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Aroma chemical signatures of wine geographical origin in relationship to grape variety, sensory characteristics, and technological factors. A case study on Valpolicella red wines

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Summary

The connection between a wine and its geographical origin is of great relevance in the context of wine production and marketing. Notions such as wine typicality and identity (at the foundation of Protected Designation of Origin), *cru* and *terroir*, all of great importance in the wine market, are based on the ability of a wine to express a 'sense of place'. The relationship between a wine and its geographical origin is in large part associated with distinctive sensory characteristics, aroma in particular, characterizing wines from specific areas. From a chemical point of view, this implies the existence of unique and specific chemical profiles underlying recognizable sensory features of wine identity and typicality. In spite of the many studies aimed at characterizing the wines of different wine regions, the chemical bases of such aroma typicality are still poorly understood. The main aim of this study was therefore to investigate the existence of unique aroma signatures of Valpolicella Corvina and Corvinone wines from specific geographical origin. For this, grape from five different vineyards were harvested and vinified during three consecutive vintages, and the wines obtained were submitted to chemical and sensory analyses aimed at identifying quantifiable chemical markers and sensory parameters. Although large quantitative differences exist across different vintages, results highlighted the existence of clear chemical patterns distinguishing the wines from each vineyard. We define these aroma chemical signatures of geographical origins. The main drivers associated with these chemical signatures were terpenes and norisoprenoids, but also compounds mostly associated with fermentation, such as branched chain ethyl esters and acetate esters. The fact that the drivers of distinction were deriving both from grape and fermentation imply that the link between a wine's composition and its geographical origin is the result of complex interactions between grape composition and yeast response to grape related factors. Among these, grape concentration of aroma precursors and YAN play a central role. The work also allowed to highlight patterns of odor similarities across the wines, providing evidence also for a sensory dimension of wine geographical identity.

Evaluation of the impact of different S. *cerevisiae* strains on aroma signatures of geographical origin indicated that area of origin has a greater impact than yeast. In fact, from a chemical point of view, most volatile compounds that are thought to influence wine aroma were primarily affected by grape composition. Sensory analysis confirmed that grape composition induces greater

differences than yeast strain too. Lastly, since a period of ageing is mandatory for most Valpolicella wines according to the product specification, the influence of aging on the aroma chemical signatures of the different wines was studied. Despite strong transformations of volatile chemical profile, aged wines retained an aroma chemical signature that was characteristic of their geographical origin. The results of this part of the work also allowed to clarify the role of different possible precursors in the formation of the potent balsamic/minty odorants 1,4- and 1,8-cineole during wine aging.

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Introduction

Wine identity: why so interesting?

In a context in which the standardization of products, including food and beverages, is the norm and the goal, wine production is characterized by a strong drive towards the expression of quality features that can be associated with unique and distinctive wines. Product quality is a complex topic that has to do with intrinsic, extrinsic, individual and cultural factors, and wine quality in particular, with its quasi-aesthetic character (Charters, et al., 2005), is particularly hard to define. Many studies question about what is and how to measure wine quality both from the product and consumer's point of view (Parr, *et al*., 2020) (Hopfer, *et al*., 2014) (Valentin, *et al*., 2016) (Charters, *et al*., 2006).

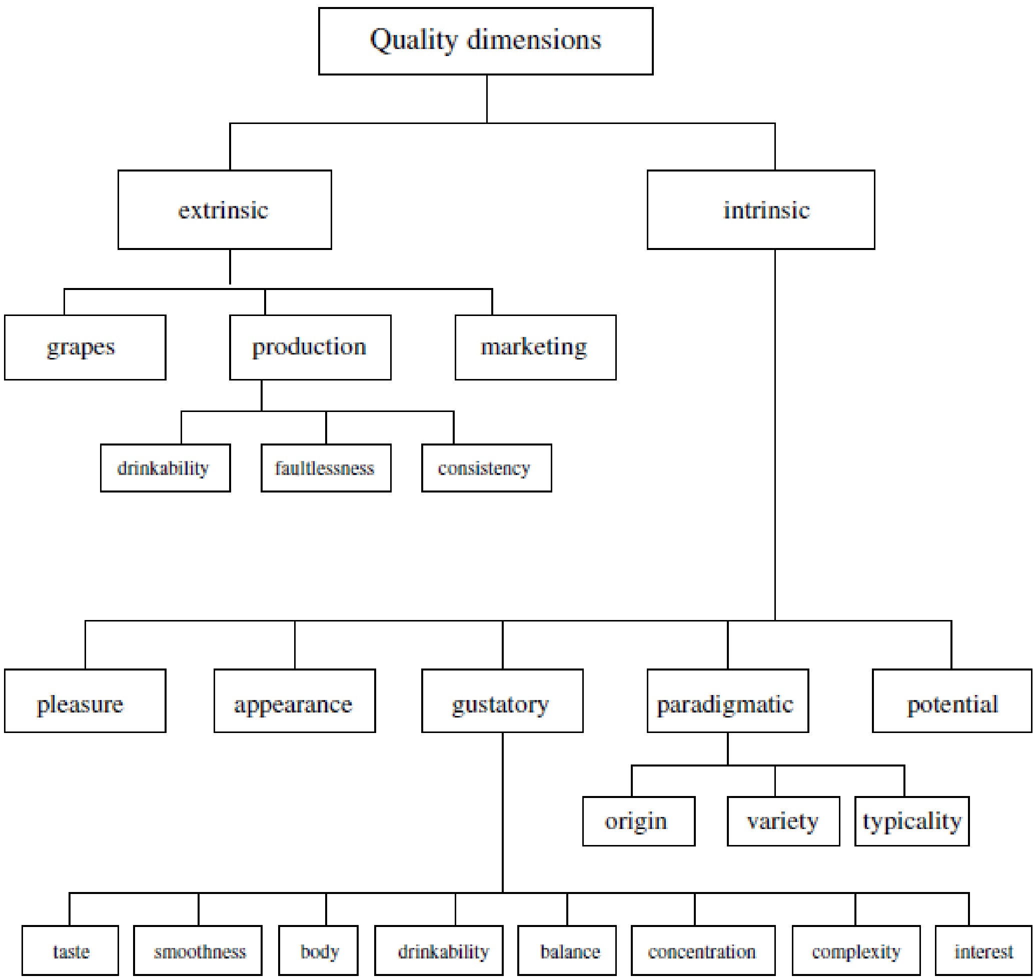


Figure I.1. Wine quality dimensions (Charters, et al., 2007)

Wine drinkers perceive wine quality as multi-dimensional experience (**Figure I.1**) (Charters, et al., 2005), in which a number of intrinsic and extrinsic factors contribute. Among these, some extrinsic dimensions are directly connected to the winemaking process (grape variety, production process, faultlessness) and are to a certain extent under the direct control of the winemaker. Conversely, the intrinsic dimensions are more strictly connected to consumers' experience, referring to sensory qualities as well as to other more complex aspects of consumers approach to wine. Among the latter, 'paradigmatic' is an interesting quality dimension involving a comparative process with an ideal reference wine, therefore linking sensory sub-dimensions (taste, complexity, concentration etc) to certain extrinsic qualities such as grape variety, geographical origin, brand, vintage.

Within this paradigmatic dimension, another component associated with wine quality and often used in wine communication and having important implication at the regulation level is 'typicality' (Charters, *et al.*, 2007). This can be defined as "the degree to which a wine reflects geographical origin and varietal purity" (Parr, 2018). Because wine is the result of a production process, we can say that the ability of a wine to express these components arises from the interaction of grape variety, environment, and production technology. At the same time, because sensory (eg. taste and aroma) evaluation is one central element of wine appreciation, the combination of these factors has to give rise to a pool of sensory characteristics leading to wine recognition, and therefore to a wine's identity. Of course, this identity can be more easily recognized when comparing wines from different varietal origin (for example a Muscat compared to a Sauvignon blanc), while it is a more complex issue when we consider wines of the same variety but of different geographical origin. And even more so when wines of the same variety and from different sub-regions (down to the scale of single vineyard parcels) within the same geographical origin are compared. Yet, this level of recognizability has an impact on consumers' behaviours so that in an increasingly competitive global market there is a trend towards linking wine marketing with identity to increase sales. Identification of key wine compositional (e.g. aroma chemical) markers associated with varietal and geographical differences within a specific wine type is one central aspect of the present research work.

In the context of wine production and marketing, the concepts of typicality or identity and in particular their connection with wine geographical origin are often expressed through other notions such as for example *terroir* and *cru*. Terroir is a common term in the wine lexicon, referring to a complex concept which takes into consideration not only the geographical characteristics but also the interaction with man both from a technical and cultural point of view. The International Organisation of Vine and Wine (OIV) defines it as follows: "*Vitivinicultural "terroir" is a concept which refers to an area in which collective knowledge of the interactions between the identifiable physical and biological environment and applied vitivinicultural practices develops, providing distinctive characteristics for the products originating from this area" "Terroir" includes specific soil, topography, climate, landscape characteristics and biodiversity features*" (OIV, 2010). As such, terroir expresses the relationship between the features of a product and its geographical origin influencing these features (Van Leeuwen, *et al*., 2006), and a central element to consider while understanding terroir is the interaction of the factors contributing to it (Seguin, 1988). Climate in terms of temperature, rainfall and solar radiation, soil in terms of geology and pedology, water uptake and agronomic techniques, are all central factors in defining terroir, (Van Leeuwen, *et al*., 2006), although due to its interactive nature terroir should be studied with a holistic approach.

The concept of *cru* originated in France, where it is used to develop hierarchical system of wine quality classification. However, even in France it has different meanings according to the region and its legislation, in Burgundy essentially coinciding with the definition of terroir. More in general, cru can be defined as a relatively small portion of a larger grape growing region in which the interaction of different factors (pedoclimatic, meteorologic, and human) results in grapes that are systematically associated with wines having recognizable and therefore 'typical' features (sensory, chemical, or combinations thereof). As such, a cru wine can be more generally defined a single vineyard wine, namely a wine produced exclusively from grapes deriving from a single vineyard block (cru) that has been recognized for its intrinsic ability to produce wines with recognizable features and of outstanding quality.

For a wine legislation perspective, the factors that are potentially associated with the existence of supposed identity, terroir or cru features are contemplated in the Protected Designation of Origin (PDO) systems. These are essentially regulatory tools created for the enhancement of rural areas, primarily from an economic point of view, linking certain characteristics of the product to its geographical origin (Barker, 2005). Although mainly based on legal purposes, the link between a geographic origin and the products, in this case wine, may also be expressed as sensory features, meaning that particular PDOs can produce unique sensory profile, different from wines produced in different areas (Parr, 2018). In Italy, wine PDOs include IGT, DOC and DOCG. They are based on a hierarchical structure, with the latter being considered qualitatively superior and subject to stricter regulations. There is a great deal of attention around PODs in Italy, for being a growing market despite the recent COVID-19 pandemic, so that efforts are being made to increase the number of appellations for greater market segmentation (Scozzafava, *et al*., 2018) (De Mita, 2020). Although the majority of Italian PDOs do not consider single vineyard classification, some exceptions exist, the most notable being the Barolo DOCG in which the appellation regulation foresees the use of 181 non-hierarchical "additional geographical mentions" (menzione geografica aggiuntiva) which refer to sub-regions within the appellation, with surface varying from 1.4 hectares up to 380 hectares (Gazzetta Ufficiale 51, 02.03.2007)

The economical relevance of expressing the link between a wine and its place of origin, in particular through its sensory features, has been addressed by a number of studies. In a recent survey of Italian consumers choices performed by Vinitaly Nomisma Mercato Italia, wine area of origin emerged as the main factor behind the choices of Italian wine consumers, followed by denomination respectively with 24 and 20% (Nomisma, 2019). Other features such as, for example, the company brand, environmental sustainability and packaging, have been considered much less important in the choice made by the consumers. These considerations are also supported by studies conducted in other European countries, where not only the origin of the wine has been chosen as the most important attribute in orienting wine choice, but it was also found a consumers willingness to pay more for a wine whose origins are certified (Bernabéu, *et al*., 2001) (Skouras, *et al*., 2002) (Lai, *et al*., 2008) (Vecchio, *et al*., 2019). Identification of geographical origin exerts undoubted commercial attraction, in particular when product typologies are referring to it explicitly (Brenna, *et al*., 2005), and when referred to small production areas (Dall'Asta, *et al*., 2011). Therefore, typicality can act as an important lever to increase wine added value since a typical wine possesses qualities that identify and differentiate (Scozzafava, *et al*., 2016). According to Easingwood, *et al*., (2011), regionality (another term used to indicate geographical typicality) deals with concepts like uniqueness, scarcity and perceived quality over time. The connection of a wine with its territory is therefore fundamental, and all those actions that tend to strengthen this tie can increase the value of the product as perceived by the consumers (Scozzafava, *et al*., 2016). Nevertheless, except for a few winemaking regions, in the majority of the cases there is limited capacity to implement integrated strategies of valorisation of wine local productions through the development of actions aimed at understanding and communicating the uniqueness of a specific wine.

A first issue in this respect concerns the difficulty in defining attributes such as identity and/or typicality of a given wine. Ideally, identity is mostly associated with recognisability. For example, at an aroma level, this implies that, across a given sample set, a number of wines share a similar aroma profile and therefore they have a common aroma identity. Typicality by definition requires the existence of a pre-established reference type, to which individual samples can be associated based on sensory properties (Moio, *et al*., 1993) (Garrido-Bañuelos, *et al*., 2020). In this sense, wine identity is a dimension that, in the context of wine quality, should be considered above the 'typicality' and 'paradigmatic' ones, as we can assess the existence of a certain identity without a prior definition of which type this identity should reflect.

In addition, at a more strictly viticultural and winemaking level, our ability to develop production strategies allowing to obtain wines expressing such sense of place is still relatively limited (Bramley, 2016). Of course, over decades or centuries of production, regional specificities have been established, such as for example the selection of grape varieties as well as viticultural and winemaking practices, leading to a good extent to geographical typicality as we know it today. However, both due to cultural and climatic factors, the boundaries of these identity features are likely to change over time (Borghini, 2012). Nevertheless, it is of primary importance to develop a wealth of knowledge concerning the actual drivers behind the ability of a given wine to express its connection with the geographical origin (Ugliano, 2019), in order to be able to effectively manage the transition to new models of grape growing and winemaking accordingly. In particular, in consideration of the central role of wine olfactory properties to the expression of its geographical identity (Ballester, *et al*., 2005), particular attention should be given to identifying the odour-active compounds that can be more directly associated with aroma identity and typicality. However, a further source of complexity is represented by the fact that wine aroma is not simply the additive result of the contribution of all aroma active compounds. Perceptive interaction phenomena have a strong impact on red wine aroma and are difficult to predict in such a complex matrix. Several works identified enhancing and synergistic or masking effect of several compounds, in particular on fruity, floral and balsamic aroma (Ferreira, *et al.,* 2002) (Atanasova, *et al.*, 2004) (Cameleyre, *et al.*, 2015) (Antalick, *et al*., 2015) (Ribéreau-Gayon, *et al.*, 1975).

This leads to a more general issue that is common in the investigations concerning complex dimensions such as identity or typicality, namely how they can be measured. Recent studies indicated that this task is actually not trivial (Maitre, *et al*., 2010). First, because it can (should) be explored from two the points of view of both producer and consumers (Giraud, 2003). Second, because of the interaction with the human factor, with the different meteorological variables and, above all, with the vintage makes difficult to identify and possibly typify metabolic and sensorial profiles that can be traced back year after year to a certain geographical origin. Exploring such complex component of wine quality is in practice more difficult than exploring varietal typicality (Maitre, *et al*., 2010).

It should be specified that many studies correlating wine to its origin have nothing to do with the issue of expressing a wine sense of place, but with its traceability and authenticity in the process of food quality control (Nasi, *et al*., 2008) (Palade, *et al*., 2014) (Hu, *et al*., 2019), in which they rarely consider the sensory implications of geographic origin. In this respect, Perrin (2008) and Ballester *et al*. (2008) demonstrated that typicality can be defined for specific wine types, although they also demonstrated that not all wines within a particular type are actually able to express such typicality.

At a more strictly chemical level, there are many studies evaluating wine volatile profile diversity in relationship to geographical area, country or producing region. However, these studies were not able to reveal measurable markers that can be associated with geographical typicality, as were either carried out considering only one vintage so that they were mostly highlighting the wine volatile diversity associated with different geographical origins (Sabon, *et al*., 2002) (Robinson, *et al*., 2014) (Garrido-Bañuelos, *et al*., 2020) (Slaghenaufi, *et al*., 2019). In other cases, the results supported the existence of chemical patterns that could be linked to wine origin, but these were in the form of non-identified metabolic features, so that actual identity of key compounds as well as their possible sensory contribution remained unclear (Roullier-Gall, *et al.*, 2014a) (Roullier-Gall, *et al*., 2014b). Interestingly Anesi, *et al*. (2015) studying the grape from the same Corvina clone from several vintages and different close sub-regions within Valpolicella area, found a terroir-specific effect on grape transcriptome regardless of vintage, this also leading to specific terroir-related metabolomic profile.

Red wines volatile compounds in relationship to wine identity: the notion of aroma chemical signature

Aroma profile is one of the most important features in the expression of the geographic identity and sensory uniqueness of a wine. Characterization of aroma chemical and olfactory markers is therefore of considerable interest for the production of wines that are expressing specific geographic identities. Wine aroma is the product of a biochemical and technological series of steps (Bayonove *et al.*, 1998) (Kotseridis, *et al.*, 2000), resulting from the contribution of different volatile molecules deriving from grapes, fermentations, and reactions linked to aging, and sometimes oak and other woods. To date, more than 800 volatile compounds such as alcohols, esters, phenols, monoterpenes, norisoprenoids, lactones, aldehydes and ketones have been identified (Etievant, 1991), even if aroma active compound in wine are between 50 and 60. Many of the aroma metabolites are present in various precursor forms in the grape, and their occurrence can be deeply influenced by vineyard characteristics and geographical location (Seguin, 1988). Among this range of volatile compounds some have been more clearly linked to wine geographical origin. The majority of these are compounds originally present in the grapes, so that a connection with the area of vineyard origin is somewhat expected. Nevertheless, from the analysis of the literature there are two aspects that emerge in this respect. First, most studies establishing a link with grape-derived aroma compounds and grape origin are limited to grape and don't consider wine. Therefore, their contribution to establishing a connection between wine aroma identity/typicality is relatively limited, especially in the case of wines from non-aromatic varieties, where many key aroma compounds are formed during vinification and aging. Second, as it is well known that vintage conditions have a major impact on grape and wine composition, in order to establish a link between wine aroma composition and its geographical origin, one should be able to demonstrate the existence of recurring patterns of volatile composition that could be associated with grape origin beyond other possible variables. Moreover, considering that aroma identity of a wine arose from the contribution of all the odor-active volatile present, volatiles not directly related to grape but to other factors, for example those ex-novo produced by the yeast (e.g. esters), should be also included. Such comprehensive information would be considered an aroma chemical signature specific of individual wines, in which recurring compositional patterns associated to grape origin become markers of geographical identity.

Terpenoids

Terpenoids are secondary metabolites of plants, with a large number of individual compounds known. Monoterpenoid class with fruity, floral and balsamic, resin-like odours is usually associated with white wines produced from aromatic grape varieties such as Muscat (Waterhouse, *et al.*, 2016), even if recently a possible contribution to red wine aroma has been suggested (Antalick, *et al., 2015)* (Slaghenaufi, *et al*., 2019). Many studies shows that terpenoids compounds form the base for sensory expression of wine aroma typical of a variety and that they can therefore be used analytically for varietal characterization (Mateo, et al., 2000). Unlike most of the aromatic constituents of wine, terpenes mainly derive from grapes (Strauss, et al., 1986). Monoterpenes are produced in grape by mevalonic acid pathway occurring in the cytoplasm or by 2-C-methyl-D-erythritol-4- phosphate pathway occurring in the plastid organelles. Monoterpenoids in grapes exist in three forms, as free monoterpene, form in which are volatile and may contribute to wine aroma, as the polyhydroxylated forms of di- or triols, and glycosidically conjugated forms, odorless and not volatile (Jackson, 2008) (Maicas, *et al*., 2005). In addition to varietal origin, *S. cerevisiae* can influence terpene profile synthesizing de novo small amounts, enzymatically hydrolysing the glycosidic bond of glycoconjugates terpenes (Williams, *et al.,* 1982) (Ugliano, *et al*., 2006) (Ugliano, *et al*., 2009) or bio transforming some of them (Gramatica, *et al.*, 1982) (Yuan, *et al*., 2011). Linalool (orange blossom), geraniol (rose), nerol (rose, citrus), β-citronellol (citrus, floral), and α-terpineol (lilac, fresh) are the more important aroma active monoterpenes (Ugliano, *et al*., 2009) in young wine. Recently, terpenoids associated with the secondary metabolism of limonene have been identified in Bordeaux red wines. Among them piperitone, (-)-mintlactone (+)-isomintlactone, menthofurolactone and menthofuran have positive coumarin- and mint-like nuances, and odor thresholds in the range of pg/L to ng/L (Picard, *et al.*, 2016) (Picard, *et al*., 2017).

Sesquiterpenes, formed in grape berries through both MVA and DOXP/MEP pathways are far less studied than monoterpenes, since are generally considered less volatile and aroma-active. However, rotundone, a sesquiterpene initially identified in Australian Shiraz wine and subsequently detected in many varieties like Graciano, Durif, Mataro, Pinot Noir, Cabernet Sauvignon, Schioppettino, Vespolina and Grüner Veltliner, has found to be one of the most potent wine aroma compounds (detection threshold in the order of ng/L) and has been associated with hints of 'black pepper' (Wood, *et al*., 2008).

Terpenoids are influenced by several factors, including climatic, environmental and agricultural factors. For example, the contribution of temperature on their levels is known (Alessandrini, *et al*., 2016), as well as that of rainfall (Dieguez, *et al*., 2003) sunlight exposure (Belancic, *et al*., 1997), water avaibility (Koundouras, *et. al.,* 2006), altitude (Alessandrini, *et al*., 2016) and soil type

(Coelho, *et al.*, 2009). Many studies, indeed, report an influence of grapes origin on the terpene content even if considering considerable geographical distances (Sabon, *et al*., 2002) (Ji, *et al*., 2008) (Celik, *et al*., 2015) (Villanova, *et al*., 2007) (Úbeda, *et al*., 2017) (Wen, *et al*., 2015) (Black, *et al.*, 2015) (Picard, *et al.*, 2016) and few considering close vineyards or parcels (Slaghenaufi, *et al*., 2019).

Norisoprenoids

Norisoprenoids, potent odor compounds, are breakdown products of carotenoids, mainly β-carotene and neoxanthin, (Winterhalter, *et al*., 2001) (Mendes Pinto, 2009). Carotenoids occurence is affected by several factors including, climate, ripeness, soil characteristics and viticulture practices (Marais, *et al*., 1992) (Sabon, *et al*., 2002) (Mendes Pinto, 2009). Norisoprenoid are divided into two chemical groups, megastigmane and non-megastigmane. Their production involves both non enzymatic and enzymatic reactions (Walter, *et al*., 2011). However, norisoprenoids can arise either by direct degradation of carotenoids or via glycosylated intermediates (Ribereau-Gayon, *et al*., 2006). β-damascenone is the main megastigmane norisoprenoid with quince aroma, the capacity of enhancing fruity aromas and a very low odor threshold on the order of ng/L (Kotseridis, *et al*., 1999) (Pineau, *et al*., 2007). The other important norisoprenoid megastigmane is β-ionone, which has a low perception threshold, in the range of ng/L and aroma of violets (Ribereau-Gayon, *et al*., 2006). Among non-megastigmane C13-norisoprenoid 1,1,6-trimethyl-1,2-dihydronaphtalene (TDN) and Vitispirane with typical kerosene and camphorated scents. As for terpenes the influence of grapes origin on their content is known (Sabon, *et al*., 2002) (Slaghenaufi, *et al*., 2019) as well as the influence of variable such as soil (Mendes Pinto, 2009), humidity, temperature (Marais, *et al*., 1992), sunlight exposure (Razungles, *et al*., 1998) (Lee, *et al*., 2007) and viticultural practices (Mendes Pinto, 2009).

Benzenoids

Benzenoids, are important wine odor active compounds, with spicy, dried fig, tobacco, and chocolate aromas (Francis, *et al*., 1998.). Wines volatile benzenoids are not only extracted by oak and other woods during cask aging but may also derive from grape precursors then transformed by microbiological or chemical processes (Waterhouse, *et al*., 2016). For example, vanillin derivatives can be produced by yeast as by-product of ferulic acid metabolism (Huang, *et al*., 1993) and some of these (e.g. vanillic acid) could be esterified by yeasts. Some of them like phenylacetaldehyde, benzaldehyde, and benzyl acetate derives from l-phenylalanine, formed through the shikimic acid pathway in plastids (Orlova, *et al*., 2006). Their content in wine depends on grape content, which is influenced by a number of *terroir* factors, including water availability, sunlight exposure and environment temperature (Robinson, *et al*., 2014) and can therefore be influenced by grape origins (Slaghenaufi, *et al*., 2019). Unpleasant, with leather and barnyard scents, are benzenoids produced mainly by *Brettanomyce*s sp. and *Dekkera* by breaking down hydroxycinnamic acids to vinyl phenols and subsequently to ethyl phenols (Robinson, *et al*., 2014).

Methoxypyrazines

Methoxypyrazines like 3-isobutyl-2-methoxypyrazine, 3-isopropyl-2-methoxypyrazine, 3-secbutyl-2-methoxypyrazine, 3,5-dimethyl-2-methoxypyrazine are nitrogenated heterocycles responsible for distinctive herbaceous and vegetative aromas like green pepper and asparagus, or even earthy (Ribereau-Gayon, *et al*., 2006). These compounds have a very low odor threshold in the ng/L range. Their origin is mainly varietal, providing characteristic odors of bell pepper to some varieties like Cabernet Sauvignon, Sauvignon blanc, Cabernet franc and Merlot (Cullere´, *et al*., 2019), but not in all wines they contribution is considered positive (Ribereau-Gayon, *et al*., 2006). Amino acids metabolism is involved in methoxypyrazines formation pathway in the grapes (Ribereau-Gayon, *et al*., 2006). Leucine and valine are thought to be the initial source of methoxypyrazines (Dunlevy, *et al*., 2013). Pyrazine levels are significantly impacted by *terroir* related parameters such as soil type (Ribereau-Gayon, *et al*., 2006), sunlight exposure, humidity (Sidhu, *et al*., 2014) and temperature (Lacey, *et al*., 1991).

Higher alcohols

Higher alcohols are alcohols with two or more carbon atoms with higher molecular weight and boiling point than those of ethanol (Lambrechts, *et al*., 2000). They are produced by yeast in the attempt to synthesize the necessary proteins from available amino acids of the medium. After amino acid deamination yeasts can excrete amount of higher alcohol after decarboxylation and subsequently reduction of ketonic acids through the Ehrlich pathway although other pathways may contribute (Ribereau-Gayon, *et al*., 2006). Their contribution to the aromatic characteristics of the wine is to be considered negative, except for phenyl ethanol with its rose-like aroma. Isoamyl alcohol show solvent-like odor and methionol unpleasant and persistent cooked cabbage hints. In general, higher alcohols should be avoided (Ribereau-Gayon, *et al*., 2006), also for their capability to suppress the fruity parameter (Ferreira, *et al*., 2016). Yeast strain, sugar content, pH, temperature, aeration are the variables incrementing higher alcohols production (Fleet, *et al*., 1993). Deficiencies of nitrogen source, ammonia and primary amino nitrogen, can lead to increased content.

Fatty Acids

Wine contains a mixture of straight chain fatty acids and branched-chain fatty acids. Among these, acetic acid is the most present and the most impacting from a sensory point of view, representing beyond 90% of total volatile acidity (Ugliano, *et al*., 2009). Its contribution to the aromatic profile of the wine is detrimental, with the classic acetic and vinegar scents, and its occurrence is due to acetaldehyde oxidation by yeast's aldehyde dehydrogenases (Dubois, 1994) (Ugliano, *et al*., 2009). Acetic acid is produced by yeast during fermentation, however, its concentrations can increase considerably through the metabolism of spoilage yeast and acetic acid bacteria (Bartowsky, *et al.*, 2008). Moreover, high values of volatile acidity, a chemical parameter directly associated with acetic acid content, could impede wines from commercialization when legal limits are exceeded (1.08 g/L in white and rosè wines, and 1.2 g/L in red wines in European Union). Straight-chain fatty acids are by-products of metabolism of saturated fatty acids during the production C16 and C18 fatty acids. Their contribution to the aromatic bouquet of the wine is mainly detrimental and their odor threshold is quite high in the order of mg/L. Sour, vinegar, cheese, sweaty, rancid, fatty, pungent, oily, rancid, are some of the descriptors attributed to hexanoic, octanoic acid and decanoic acids, wine's most present fatty acids (Lambrechts, *et al.*, 2000). There are, however, some evidence that positively correlates wines fruity character with fatty acid content (San-Juan, *et al*., 2011) (Hu, *et al.*, 2018). Yeast strain, sugar concentration, nutrient balance, fermentation temperature, pH and aeration can modulate the occurence fatty acids (Ugliano, *et al*., 2009). Branched-chain fatty acids like methylpropanoic, 2-methylbutanoic and 3-methylbutanoic acids have also a negative impact on wine aroma. Their presence is linked with the amino acids' catabolism (Ugliano, *et al*., 2009).

Esters

Fermentative esters have a key role in the aromatic profile of the wines, being largely responsible for fruitiness and pleasant smells. Referring to esters we actually refer mainly to two groups, the acetate and the ethyl esters. Acetate esters are synthesized from higher alcohols and acetyl-CoA mediated by acetyltransferases (Lambrechts, *et al*., 2000) (Verstrepen, *et al*., 2003). Main acetate esters in wine are ethyl acetate (apple), isoamyl acetate (banana), hexyl acetate (berry) and 2-phenylethyl acetate (floral, rose). Ethyl fatty acid esters formation is different from that of acetic esters, and to date still not fully understood. Low molecular weight ethyl fatty acid esters like ethyl propanoate (fruity, pineapple) and butanoate (fruity, peach) derived from α-ketobutanoate (Eden, *et al*., 2001). However, it is thought that most fatty acids ethyl esters are derived from the early stages of lipid biosynthesis (Suomalainen, 1981), through the esterification of acyl-CoA. Ethyl hexanoate, octanoate and decanoate are the main ethyl fatty acid esters. The production of esters is modulated by different fermentation variables, compositional and process. Grape maturity, sugar, as well as intrinsic lipid composition and nitrogen content and composition have an influence on esters profile (Houtman, *et al*., 1980) (Henschke, *et al*., 1991) (Yoshimoto, *et al*., 1998) (Saerens, *et al*., 2008) (Antalick, *et al*., 2015). Branched-chain fatty acid ethyl esters (methyl propanoate, ethyl 2-methylbutanoate, and ethyl 3-methylbutanoate) are characterized by red fruit and strawberry aromas and low perception threshold (between 3 and 18 μg/L) often exceeded (Guth, 1997) (Piombino, *et al*., 2004) (Ferreira, *et al*., 2000). Their origin is due to the esterification of branched-chain fatty acids linked to amino acid metabolism (Ugliano, *et al*., 2009).

C_6 Alcohols

C_6 alcohols are compounds with green and grassy notes. Hexanol, trans and cis-3-exen-1-ol, and trans and cis-2-hexen-1-ol are the main C_6 alcohols in wine. They are formed from enzymatic oxidation of fatty acids, α-linolenic and α-linoleic, during grape crushing in pre-fermentative stage (Waterhouse, et al., 2016). Unsaturated fatty acids are released thank to lipase enzyme that hydrolyses the glycerolipids, then lipoxygenase enzyme hydroperoxides convert them to their corresponding hydroperoxides and hydroperoxide-lyase cleaves the hydroperoxides to the C_6-aldehydes. C_6-aldehydes are isomerized or reduced to C_6 alcohols by additional enzymes, during fermentation (Waterhouse, *et al*., 2016) (Ugliano, 2009). C_6 compounds depends not only on the content of precursors, unsaturated fatty acids, but also grape enzymatic activities, determining the varietal character of these compounds (Valentin, 1993) (Rapp, *et al*., 1993) (Xu, *et al*., 2017). The presence of C_6 occurs during the pre-fermentative stage, therefore, besides ripening and variety, technological variables like extent of maceration, solids contact, oxygen availability, SO_2, temperature, leaf presence have a major impact (Waterhouse, *et al*., 2016). Interestingly some of these compounds have been indicated as markers of geographical origin for wines produced with the same cultivar (Oliveira, 2000) (Oliveira, *et al*., 2006). Among the terroir related factors, water status seems to have a significant influence on the levels of C_6 alcohols (Giordano, *et al.*, 2013) (Talaverano, *et al.*, 2017).

Sulfur compounds

Sulfur compounds are volatile metabolites providing different aroma descriptors which can be both positive and negative (Waterhouse, *et al*., 2016). Some of them like hydrogen sulfide, methanethiol, ethanethiol and ethyl and methyl thioacetates are responsible for certain negative scents, typical of so-called reduction, attributable to rotten eggs descriptor (Siebert, *et al*., 2010). These compounds are linked to yeast production of hydrogen sulfide during fermentation, in the attempt of incorporation into sulfur-containing amino acids (Waterhouse, *et al*., 2016). The occurrence of dimethyl sulphide (DMS), a compound which in purity smells of truffles but in wine contributes to enhancing fruitiness parameter (Escudero, *et al*., 2007), is mainly due to grape precursors. In fact, despite yeast can produce small amount from precursors such as DMSO and some sulfur amino acids, the amount produced during fermentation is low, and most of it, is stripped off by CO_2 (Baumes, 2009). S-Methyl methionine (PDMS), is the major precursor in grape and wine, from which DMS is released over time though an elimination reaction (Loscos, et al., 2008) (Segurel, et al., 2005). Accumulation of PDMS depends on grape varieties; but besides of genetic control, also several factors related to terroir variability, such as air temperature, water and nitrogen vine status are known to impact its levels (De Royer Dupre, 2014) (Le Menn, et al., 2019). Volatile thiols can also play a central role in the expression of certain aromatic characteristics. The low molecular weight compounds H_2S and methyl mercaptan, predominantly associated with the so-called ‘reductive’ off-odors, are produced in large part during alcoholic fermentation, although non-negligible concentration can also accumulate during wine bottle aging (Ugliano and Henschke, 2008) (Ugliano, 2013).The polyfunctional thiols 3-Mercaptohexan-1-ol, 3-mercaptohexyl acetate, 4-mercapto-4-methylpentan-2-one are mainly released from grape-derived precursors, amino acid S-conjugates, during fermentation and contribute to wine aroma with tropical, grapefruit, passionfruit, box tree and guava scents (Roland, et al., 2011) (Murat, et al., 2001). These compounds,characteristic of Sauvignon blanc wines, are also present in several white and red varieties. Thiols are impacted by different enological practices , but are also susceptible to '*terroir*' related factors such as water status (Coetzee, *et al.*, 2012).

Oak derived volatile compounds

During cask aging, some wood components can be extracted, of these, a fraction is volatile and may contribute to wine's aromatic profile. Woody, toasted, vanilla and coconut are the descriptors most associated with wines that have been aged in contact with wood. Among the most important compounds are cis- and trans-oak lactone, which presence have been identified as the cause of typical scents of barrel, bringing hints of oak and coconut (Pérez-Coello, *et al*., 2009).Thanks to hydrolysis, pyrolysis, and oxidation reactions the phenolic aldehydes vanillin and syringaldehyde and their derivatives arise form lignin fragments (Pérez-Coello, *et al*., 2009). Of these compounds, vanillin, with its typical vanilla aroma, influences the aromatic profile of the wine (Boidron, *et al*., 1988). Eugenol and isoeugenol (cloves and oak), guaiacol and its 4-ethyl and 4-vinyl derivatives (spicy, toasted) are the main volatile phenols with aroma influences arising from wood barrels (Boidron, *et al*., 1988). Many other volatile compounds with a much lower impact can be extracted from the woods, including terpenes and norisoprenoids and some with negative impact like 2-nonenal, 3-octen-1-one, 2-octenal, and 1-decanal (Pérez-Coello, *et al*., 2009).

Valpolicella: the territory, the grapes, the wines

Valpolicella is an Italian wine producing region, located north of Verona, well-known for the production of famous red wines, above all Amarone. Its territory borders on Lake Garda to the west, while to the east and north it is protected by the Lessini Mountains. It extends in the hills at the foot of the Veronese Prealps. Production area of Valpolicella appellation it is subdivided, according to the production disciplinary, in three distinct areas: *Valpolicella Classica*, made up of five geographical areas, includes the area of Sant'Ambrogio di Valpolicella, the area of San Pietro in Cariano and the valleys of Fumane, Marano and Negrar, the *Valpantena* area, including the homonymous valley, and the *Valpolicella DOC* area, with the districts of the municipality of Verona and the valleys of Illasi, Tramigna and Mezzane.

Valpolicella is characterized by a morphologically varied territory. Consisting of valleys that develop in a north-south direction, Valpolicella is ideally presented as a set of valleys that branch off from Verona. The landscape of Valpolicella is mainly hilly, with gentle slopes and watershed at low altitudes. Moreover, the close presence of Garda Lake, a large water basin, can significantly influence climatic conditions of the area. The soil composition is quite variable throughout the Valpolicella region, including sandy, clayey, sandy-gravely, sandy-clayey, silty-clayey, marly limestone (Scienza, *et al*., 2008).

The climate of Valpolicella is characterized by mild temperature, as confirmed by the presence of olive trees above 300 m a.s.l. It is influenced by the Adriatic Sea to the east, the Dolomites to the north and the Garda lake to the west. Lessinia plateau to the north protect the region from climate extremes and during summer provides fresh winds. The south, open and wide, have a warm, climate. The lands close to Garda lake, thanks to winds coming off the lake show lower high temperatures and less diurnal variation. Temperature of winter are higher on the hill than in plain, and rarely fall below 0 °C; during summer temperature ranges between 25 and 30 and between 18 and 20 °C respectively during day and nights. Average rainfall varies from lowland to higher hills, from 850 mm/year to 1200 mm/year. Rainfall is usually rare during winters, more frequent in spring and autumn but summer rains are not uncommon, more abundant in mountains and hillside than in plains. The Bora, the main wind of the region blows from northeast, and the South wind from the southeast. During summer characteristic breezes blowing from south to north, generates temperature fluctuation facilitating the accumulation of aromatic compounds (Jackson, 2011). Valpolicella has always been considered a wine-growing area, ever since the days of ancient Rome, when the “Retico wine” that Augustus liked so much was produced by Catullus there (Paronetto, 1981). One characteristic of Valpolicella wines lies in the unique blend of grape varieties used in wine production, including three main varieties, namely Corvina, Corvinone, and Rondinella, and a range of other minor varieties (Gazzetta ufficiale 190, 14.08.2019). All the three main varieties as well several of the minor varieties such as Oseleta and Molinara are to a very large extent grown exclusively in the province of Verona (Vanzo, 2018) (Slaghenaufi, *et al*., 2021). The second main characteristic of Valpolicella PDO is the use, in certain wine categories, of grapes that are submitted to post-harvest withering. This is rather unique in the context of red wine, especially for the production of a dry red wine such as Amarone.

Nowadays, Valpolicella appellation includes various wine types, such as Valpolicella, a light-bodied red produced with fresh grapes, Valpolicella Superiore, Amarone, a dry wine, produced with withered grapes, and Recioto, a sweet wine, also produced with withered grapes. Within the Superiore category, a particular wine style named Ripasso is produced by re-fermenting a Valpolicella wine by adding pomace of withered grapes coming from the production of Recioto or Amarone.

According to Regione Veneto - Schedario viticolo veneto-AVEPA and Siquria spa Valpolicella vine growing surface in 2015 was 7.844 hectares, corresponding to 926.420 quintals of grapes produced (Consorzio della Valpolicella, 2017). In 2016 a total of 2286 Wineries were listed as producers of wines belonging to the Valpolicella PDO, with 60.816.009 bottles of all Valpolicella appellations being produced, worth approximately 600 million dollars (Consorzio della Valpolicella, 2017).

Figure I.2. Valpolicella map

As mentioned above, three of the Valpolicella PODs involve the use of withered grapes. For this reason, the grape withering technology is very common in Valpolicella area. This process is performed in traditional warehouse called “fruttaio”, large breezy lofts, where is continuous air exchange, where grapes undergo slow dehydration (Paronetto, 1991). The withering process is regulated by the product specifications of Valpolicella appellations. Grape in fact, must lose at least 30% of their weight and their sugar content has reached a potential alcohol content of 14% (v/v) before being employed for Amarone or Recioto productions (Gazzetta ufficiale 190, 14.08.2019).

In addition, the maximum yield of grapes in finished wine must not exceed 40%. The duration of treatment can last up to 100-120 days, in any case not before 1st of December of the harvest year (Gazzetta ufficiale 190, 14.08.2019).

Aim of the study

From the analysis of the existing literature, it appears clear that the issue of identifying, measuring and then managing the components that contribute to the ability of a wine to express a ‘sense of place’ is key to the development of successful production and communication strategies. Wine sensory properties, in particular its aroma features, are among the main drivers of such ability. In this context, a major challenge lies in the identification of volatile compounds or patterns thereof that can be associated with such sense of place. This step becomes pivotal to the development of production and communication strategies based on wine identity, typicality, sense of place.

The aim of this thesis project was to investigate, over a series of three consecutive vintages, the chemical characteristics of grape and wine aroma profiles obtained from specific vineyard parcels, in order to

- understand the chemical and sensory dimensions of single vineyard wines identity
- identify volatile compounds that are major vectors of such uniqueness
- highlight possible metabolic pathways leading to the occurrence of these compounds in wine
- evaluate the impact of specific winemaking variables on wine content of these key volatile compounds, also in relationship to unique and traditional production processes typical of certain wine regions.

Valpolicella is particularly suited for this purpose, in consideration of the uniqueness and diversity of the grape varieties employed for wine production and the combination of conventional red winemaking with traditional (withering) practices. The study was carried out taking one single winery as a production model, so that vineyard management, grape harvest decisions and other pre-requisite variables reflected real life scenarios. All wines were produced experimentally so that highly standardized protocols could be applied across the three vintages.

Chapter 1

Aroma chemical and sensory signatures of single vineyard wines

1.1. Introduction and aim

In the context of wine production, identity and typicality play a central role in wine perceived quality and value, in particular when these components are associated with specific geographical origin. Identifying and measuring markers of such geographical identity and typicality remains challenging. Nevertheless, the acquisition of such information is a key step in the process of developing winemaking and grape growing protocols and technologies for improved management of typicality in the vineyard and in the winery, including approaches of precision viticulture and enology.

The primary aim of the present work was to investigate the volatile chemical composition of wines obtained from grapes harvested in selected vineyards during consecutive vintages, and assess the existence of recurring patterns that could represent unique aroma chemical signatures. Such aroma signatures will therefore contain information concerning measurable chemical drivers of geographical identity of a specific wine category. A sensory investigation was also carried out to assess the relationship between aroma chemical signatures of the different wines and their sensory characteristics.

The study was carried out with the support of a commercial winery operating in the Valpolicella area, which provided the grapes for the production of the different wines. Accordingly, vineyard management, grape harvest decisions and other pre-requisite variables reflected real life scenarios. All wines were produced experimentally so that highly standardized protocols could be applied across the three vintages. In consideration of the peculiarities of the Valpolicella wine region, the two grape varieties representing the basis of the Valpolicella blend, namely Corvina and Corvinone, were chosen for the study. Among the different wine types belonging to the Valpolicella appellation, two production models, namely Valpolicella (light-bodied dry red wine made from freshly harvested grapes) and Amarone (full-bodied dry red wine made from grapes submitted to post-harvest withering) were considered for the experimental winemaking trials and the study of the aroma chemical signatures. A total of five vineyards were included for both varieties during three vintages.

1.2. Materials and methods

1.2.1. Vineyards and grapes

Both Corvina (*Vitis vinifera* L. *cv.* Corvina) and Corvinone (*Vitis vinifera*, L. cv. Corvinone), the two main grape varieties of the Valpolicella appellation, were employed in the study. Grapes were harvested in mid-September 2017, 2018 and 2019 in five vineyards belonging to the same winery and located in two sub-regions within the Valpolicella. Vineyards 1, 2 and 3 (V1-3) were located in the same estate located between the municipalities of Tregnago and Mezzane di Sotto, about 20 km north-east from the city of Verona (45°30'36.7"N 11°08'02.7"E) (**Figure 1.2.1**).

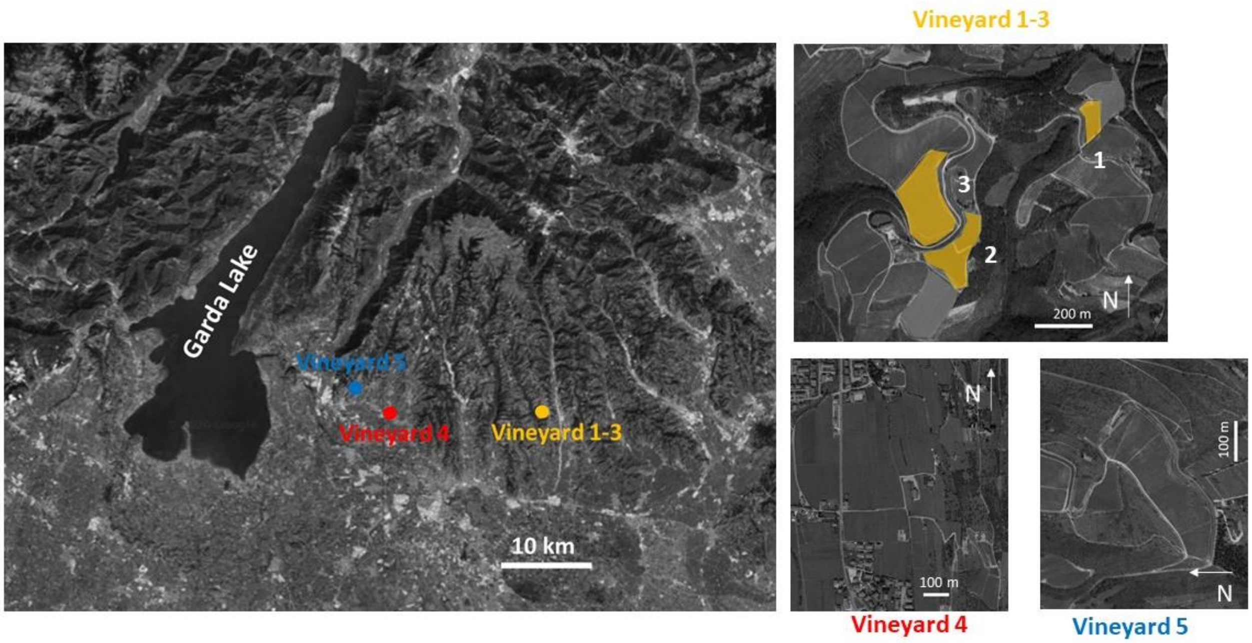


Figure 1.2.1. Geographic location of vineyards

Vineyards 4 and 5 are located in Pedemonte, near the town of San Pietro in Cariano (45°30'40.5"N 10°54'58.6"E) and San Giorgio in Valpolicella (45°32'16.6"N 10°51'19.4"E) respectively. All vineyards had the same clone-rootstock combination. Surface and characteristics of vineyards are shown in **Table 1.2.1**. Grapes were harvested and vinified from 13th to 24th of September in 2017, from 17th of September to 1st of October in 2018 and from 25th of September to the 14th of October 2019. For each vineyard, individual vines evenly scattered across the parcel (avoiding external rows) were selected for the study and the grapes for the experimental winemaking were obtained exclusively from these grapes during each vintage. Approximately 60 kg of berries were harvested.

Harvest took place following the schedule established by the winery owning the vineyards, so that grapes were processed in agreement with standard winery evaluation of maturity. In consideration of the local traditional practice of post-harvest withering of the grapes, also withered grapes have been employed, which will be detailed later. Meteorological data of the three years were obtained from meteorological stations of the Regional Agency for Environmental Protection Veneto (ARPAV), using for vineyards 1-3 the one located in Illasi (45°27'37.1"N 11°10'17.5"E, 144 a.s.l.) and for vineyards 4-5 the one in San Pietro in Cariano (45°30'33.6"N 10°53'16.9"E, 127 a.s.l.). Illasi meteorological station marked average temperature slightly higher than the station of San Pietro in Cariano up to 0.8 ºC higher during all three years of monitoring (**Appendix 1.2.1**). Considering the rainfall, apart from the year 2017 where rainfall was comparable, the Illasi station recorded a higher amount (**Appendix 1.2.2**).

Table 1.2.1. Surface (ha) and characteristics of studied vineyards

Vineyards	Surface (ha)	Characteristics
1	1	Slope 10-30%, terraced, 420–485 m a.s.l., south/south-west, sand 35–40%, clay 20–25%, silt 35–45%
2	3	Slope 20–30%, 290–345 m a.s.l., south south-east, sand 40–45%, clay 25–30%, silt 25–35
3	3	Slope 30–35%, 270–370 m a.s.l., north/south-west, sand 35–45%, clay 20–30%, silt 25–45%
4	2.5	Slope 70% terraced, 150-195 m a.s.l., west sand 45%, clay 20-25%, silt 30-35%
5	7	Slope 30% 430-500 m a.s.l., est/south-est, sand 46%, clay 17%, silt 38%

For the withering, a portion of the grapes at harvest were put in a warehouse (locally called “fruttaio”) where withering was carried out according to the procedures normally applied by the winery. Withering lasted 11-12 weeks, and in agreement with the appellation relation (Gazzetta ufficiale 190, 14.08.2019) grapes lost approximately 30% of their weight. Average conditions in the warehouse over the same period for the previous 5 years indicated a gradual temperature decrease (from 16 °C to 7 °C) and a progressive increase in relative humidity (from 55% to 80%) during the period of withering.

1.2.2. Winemaking

After manual destemming, berries were randomized to obtain batches of 12.5 kg each. From each batch, 3.5 kg were taken, hand crushed with 100 mg/kg of potassium metabisulphite and put into

5 L glass vessel. Fermentations of musts were carried out in triplicate with the same yeasts employed by the winery for the different types of wine: fresh grapes musts with *Saccharomyces cerevisiae* AWRI 796 (AB Mauri, Camellia, Australia), while withered grape musts with *Saccharomyces cerevisiae* Zinfandel (Vason, Verona, Italy). Zinfandel show a higher alcohol tolerance compared to AWRI 796 (up to 19.5% against 15.5%) and is more suitable for the production of wines from grapes with higher glucose+fructose content. Differences in the ability of the two yeasts to produce volatile compounds have been assessed in **Chapter 3**. Active dry yeast of each commercial starter was rehydrated in water at 37°C for 15 min, then 7.5 mL of each culture (100 g/L) was used to inoculate individual grape batches. Weight loss, density, Brix degrees and temperature were monitored daily. Fermentations were carried out at 22 ± 1 °C, with cap being broken twice a day by gently pressing it down skins with a steel plunger and density and temperature monitored daily. Upon completion of alcoholic fermentation (glucose-fructose < 2 g/L), wines were pressed, cold settled and then clarified by centrifugation at 4500 rpm for 15 minutes at 5° C (Avanti J-25, Beckman Coulter, California, USA). Potassium metabisulphite to a final free SO_2 concentration of 25 mg/L, after which the wines were bottled in 330 mL glass bottles with crown caps. Fermentation kinetics are shown in **Appendix 1.2.3-1.2.6**.

Grape macerates were also prepared for each grape batch in order to investigate volatile composition of samples from different vineyards in the absence of yeast activity. From each grape batch of grapes two aliquots of 800 grams were taken, hand crushed with 80 mg of potassium metabisulphite and put into 1.5 L glass vessel. 15% w/w of ethanol and 100 mg of dimethyl dicarbonate were added. The vessels were hand stirred daily and after two weeks the macerated were pressed. These grape macerates were then clarified by centrifugation at 4500 rpm for 15 minutes at 5° C (Avanti J-25, Beckman Coulter, California, USA), and bottled in 330 ml glass bottles with crown caps.

1.2.3 Standard enological analyses

Glucose-fructose, YAN, alcohol, acetic acid, and total acidity were analysed using a Biosystems Y15 multiparametric analyser (Sinatech, Fermo, Italy). For each parameter, a specific kit (Sinatech, Fermo, Italy) was used. Y15 performance, as well as LOD and LOQ are given in **Appendix 1.2.8**. Ethanol was analysed with Alcolyzer dma 4500 (Anton Paar, Graz, Austria). The pH was evaluated with a Crison Basic 20+ pHmeter (Barcelona, Spain)

1.2.4. SPE–GC-MS analysis

For quantification of alcohols, esters, fatty acids, benzenoids and p-menthane-1,8-diol, SPE extraction followed by GC-MS analysis was used, following the procedure described by Slaghenaufi, *et al*., (2019). 100 µL of internal standard 2-octanol (4.2 mg/L in Ethanol) are added to samples prepared with 50 mL of wine and diluted with 50 mL of deionised water. Samples were loaded on a BOND ELUT-ENV, SPE cartridge, (Agilent Technologies. USA) previously activated with 20 mL of dichloromethane, 20 mL of methanol and equilibrated with 20 mL of water. After sample loading, the cartridges were washed with 15 mL of water. Free volatile compounds were eluted with 10 mL of dichloromethane, and then concentrated under gentle nitrogen stream to 200 µL prior to GC injection. GC–MS analysis was carried out on an HP 7890A (Agilent Technologies) gas chromatograph coupled to a 5977B quadrupole mass spectrometer, equipped with a Gerstel MPS3 auto sampler (Müllheim/Ruhr, Germany). Separation was performed using a DB-WAX UI capillary column (30 m × 0.25, 0.25 µm film thickness, Agilent Technologies) and helium as carrier gas at 1.2 mL/min of constant flow rate. GC oven was programmed as follow: started at 40 °C for 3 min, raised to 230 °C at 4 °C/min and maintained for 20 min. Mass spectrometer operated in electron ionization (EI) at 70 eV with ion source temperature at 250 °C and quadrupole temperature at 150 °C. Mass spectra were acquired in SIM mode. A calibration curve was prepared for each analyte using seven concentration points and three replicate solutions per point in model wine (12% v/v ethanol, 3.5 g/L tartaric acid, pH 3.5) 100 Microliters of internal standards 2-octanol (4.2 mg/L in ethanol) were added to each calibration solution, which was then submitted to SPE extraction and GC-MS analysis as described for the samples. Calibration curves were obtained using Chemstation software (Agilent Technologies, Inc.) by linear regression, plotting the response ratio (analyte peak area divided by internal standard peak area) against concentration ratio (added analyte concentration divided by internal standard concentration).

1.2.5. Extraction and analysis of glycosidically-bound volatile compounds

After SPE elution of free volatile compounds with 10 mL of dichloromethane as described above glycosidic precursors were eluted with 20 ml of methanol and collected. Enzymatic hydrolysis was performed as described by Slaghenaufi *et al*. (2019). Glycosidic extracts were evaporated under vacuum thanks to Rotavapor (Buchi R-215 Rotavapor System), recovered with 5 mL of citrate buffer (pH 5), 100 mg of polyvinylpolypyrrolidone (PVPP) and 200 µL of enzyme solution AR2000 (70 mg/mL in citrate buffer) were added. Samples were stored at 37 ºC overnight. Aglycones were extracted as free volatile compounds with the SPE protocol and analysed with GC-MS technique as described above.

1.2.6. HS-SPME–GC-MS analysis

For quantification of terpenes, norisoprenoids and methyl salicylate SPME extraction followed by GC-MS analysis was used, following the procedure described by Slaghenaufi & Ugliano. (2018). 5 µL of internal standard 2-octanol (4.2 mg/L in Ethanol) are added to 5 mL of wine diluted with 5 mL of deionized water in a 20 mL glass vial. 3 gr of NaCl are added prior to GC-MS analysis. Samples were equilibrated for 1 min at 40°C. Subsequently SPME extraction was performed using a 50/30 µm divinylbenzene–carboxen–polydimethylsiloxane (DVB/CAR/PDMS) fibre (Supelco, Bellafonte, PA, USA) exposed to sample headspace for 60 min at 40°C. Desorption was done into the injector port at 250°C for 5 min in splitless mode. GC-MS analysis were performed on an HP 7890A (Agilent Technologies, USA) gas chromatograph coupled to a 5977B quadrupole mass spectrometer, equipped with a Gerstel MPS3 auto sampler (Müllheim/Ruhr, Germany). Separation was performed using a DB-WAX capillary column (30 m × 0.25, 0.25 µm film thickness, Agilent Technology, USA) and helium as carrier gas at 1.2 mL/min of constant flow rate. GC oven was programmed as follow: started at 40°C for 3 min, raised to 230°C at 4°C/min and maintained for 20 min. Mass spectrometer operated in electron ionization (EI) at 70 eV with ion source temperature at 250°C and quadrupole temperature at 150°C. Mass spectra were acquired in SIM mode.

A calibration curve was prepared for each analyte using seven concentration points and three replicate solutions per point in model wine (12% v/v ethanol, 3.5 g/L tartaric acid, pH 3.5). 100 Microliters of internal standards 2-octanol (4.2 mg/L in ethanol) were added to each calibration solution, which was then submitted to SPME extraction and GC-MS analysis as described for the samples. Calibration curves were obtained using Chemstation software (Agilent Technologies, Inc.) by linear regression, plotting the response ratio (analyte peak area divided by internal standard peak area) against concentration ratio (added analyte concentration divided by internal standard concentration). Retention indices, quantification ions of studied compounds and their LOD and LOQ are shown **Appendix 1.2.7**

1.2.7. Sensory analysis: sorting task

Sorting task was carried out to find wines sensory similitudes and differences as described by Alegre *et al*. (2017) with slight differences. A total of twelve wine experts (six women and six men) aged between 24 and 54 living in Verona participated in the study. All the panellists were wine experts (according to Parr, Heatherbell specifications (2002)) since wine-science researchers or teaching staff regularly involved in wine-making and/or wine evaluation. One hour before the test samples were removed from the 16°C cold room and 20 mL were poured in wine glasses labelled with 3-digit random codes and covered by plastic Petri dishes; all samples were served at room temperature, and wines were served in randomized order for each panellist. Panellists were asked to sort the wines into groups based on orthonasal aroma similarities. They could make as many groups as they wished. Once they had formed the groups the panellists were asked to write down their response. The panellists were not informed about the nature of the samples to be evaluated, but they were informed they were evaluating young red wine.

1.2.8. Statistical analyses

Principal Component Analysis (PCA), Partial least squares discriminant analysis (PLS-DA), one-way ANOVA (α=0.05), Kruskal Wallis (α=0.05), Discriminant Analysis (DA) and Mann-Whitney test (α=0.05) of chemical data have been performed using XLSTAT 2017 (Addinsoft SARL, Paris, France). Hierarchical Cluster Analysis (HCA) have been performed using XLSTAT 2017 (Addinsoft SARL, Paris, France).

1.3. Results and discussion

1.3.1. Wines obtained from fresh grapes

In the context of the Valpolicella appellation, light to medium-bodied dry reds such as *Valpolicella* or *Valpolicella Classico* (the latter referring to wines produced in the sub-region of Valpolicella Classica), also in the *Superiore* version, represent the lower price segment and are typically appreciated for their freshness and intense aroma profile. They are produced with blends based mostly on Corvina and Corvinone, and can contemplate a period of aging before being released (minimum 1 year for the Superiore). This part of the work is dedicated to the study of the aroma chemical signatures of this type of wines.

1.3.1.1. Overview of grape main compositional parameters in the three vintages

Analytical parameters of the grapes at harvest are shown in **Appendix 1.3.1.1**. Reducing sugars levels (glucose + fructose) content in musts at crush ranged from 160 g/L in 2018 Corvinone V2 to 249.7 g/L in Corvina V4 2019. As the present study has been carried out following the harvest schedule of a real winery, the grapes were harvested at different degrees of sugar ripeness. While this allowed to study the volatile composition of samples (grapes and wines) that were reflecting real life scenarios, the possible influence of ripeness alone in the existence of an aroma signature supporting the concept of 'cru' wines had to be considered and was assessed a posteriori, as it will be discussed later. Likewise, with regard to the nitrogen content, it was also chosen not to add any external source to ensure that the differences due to nitrogen content are entirely due to the intrinsic composition of the grapes. Even in this case the differences between the grapes were large, ranging from 56.7 mg/L in 2019 Corvina V1 to 216.4 mg/L in 2018 Corvinone V3. Despite the low YAN content of some musts, all fermentations reached a content of less than 2 g/L of glucose + fructose. pH values ranged from 2.85 to 3.32, and also in this case no modification was carried out. Main enological parameters of fresh grapes wines at the end of alcoholic fermentation are shown in **Appendix 1.3.1.2**.

1.3.1.2. Overview of different vintages volatile chemical profiles

To assess the impact of vintages and vineyards, as well as their interaction, two-way ANOVA was performed on the whole volatile chemical data set (**Appendix 1.3.1.3**). We decided to treat the varieties separately and therefore their impact on the aromatic profile will be assessed in the next sub-chapter *(***1.3.1.3. Varietal volatile patterns in Corvina and Corvinone**). The impact of vineyards was lower than that of vintages. In fact, in Corvina and Corvinone respectively 45% and 37% of the compounds were found to be affected by grape origin, most of them of varietal origin (terpenes, norisoprenoids and benzenoids), while 94% and 82% were found to be influenced by vintages. However, the Vineyards*Vintages interaction had a great impact on volatile chemical profiles, so that almost all compounds were significantly affected in both varieties. In the context of this study, the fact that the interaction between vintage and vineyards represented the main source of significant diversity between wines was an important starting point.

In order to generate a comprehensive overview of the whole data set, Principal Component Analysis was performed including volatile compounds data of wines **(Figure 1.3.1.1**). Roughly 44% of the total variance was explained with the first two principal components with PC1 accounting for 24.85% of the variance ad PC2 accounting for 18.94%. Different vintages were differentiated mainly on PC1 while the varieties on the PC2, indicating a major effect of vintage on wines volatile composition. Specifically, vintage 2017 was richer in terpenes and norisoprenoids while 2018 showed the lower contents. The variations between wines from the same vineyard and varieties reached 2-fold the total content of terpenes and 17-fold the total content of norisoprenoids. The observed differences between vintages could in part be associated with temperatures and rainfall of each season (**Appendixs 1.2.1** and **1.2.2**). For example, vintage 2017 showed, especially in August, higher temperatures and less rainfall than other years. Warmer climate can influence terpenes and norisoprenoids content (Alessandrini, *et al*., 2016) (Wen, *et al*., 2015) as well as limited water availability (Koundouras, *et al*., 2006) (Qian, *et al*., 2009). Vintage 2018, although similar temperature and total rainfall to vintage 2019, showed much higher rainfall in September, which might have contributed to lower concentration of grape-derived metabolites in wines (Dieguez *et al.,* 2003). An association between vintage and fermentation-derived volatile compounds, in particular esters, was also observed, in spite of the fact that the same vinification protocol was used every year. One first and extremely important observation that can be drawn from **Figure 1.3.1.1** is that, of the different variables considered, namely vintage, grape variety, and vineyard of grape origin, vintage had the greates influence. This has great relevance for the objectives of this work, as our purpose is to identify markers of geographical identity at the level of individual vineyards and beyond the influence of other variables, including vintage. Implications of this will be discussed later in the chapter.

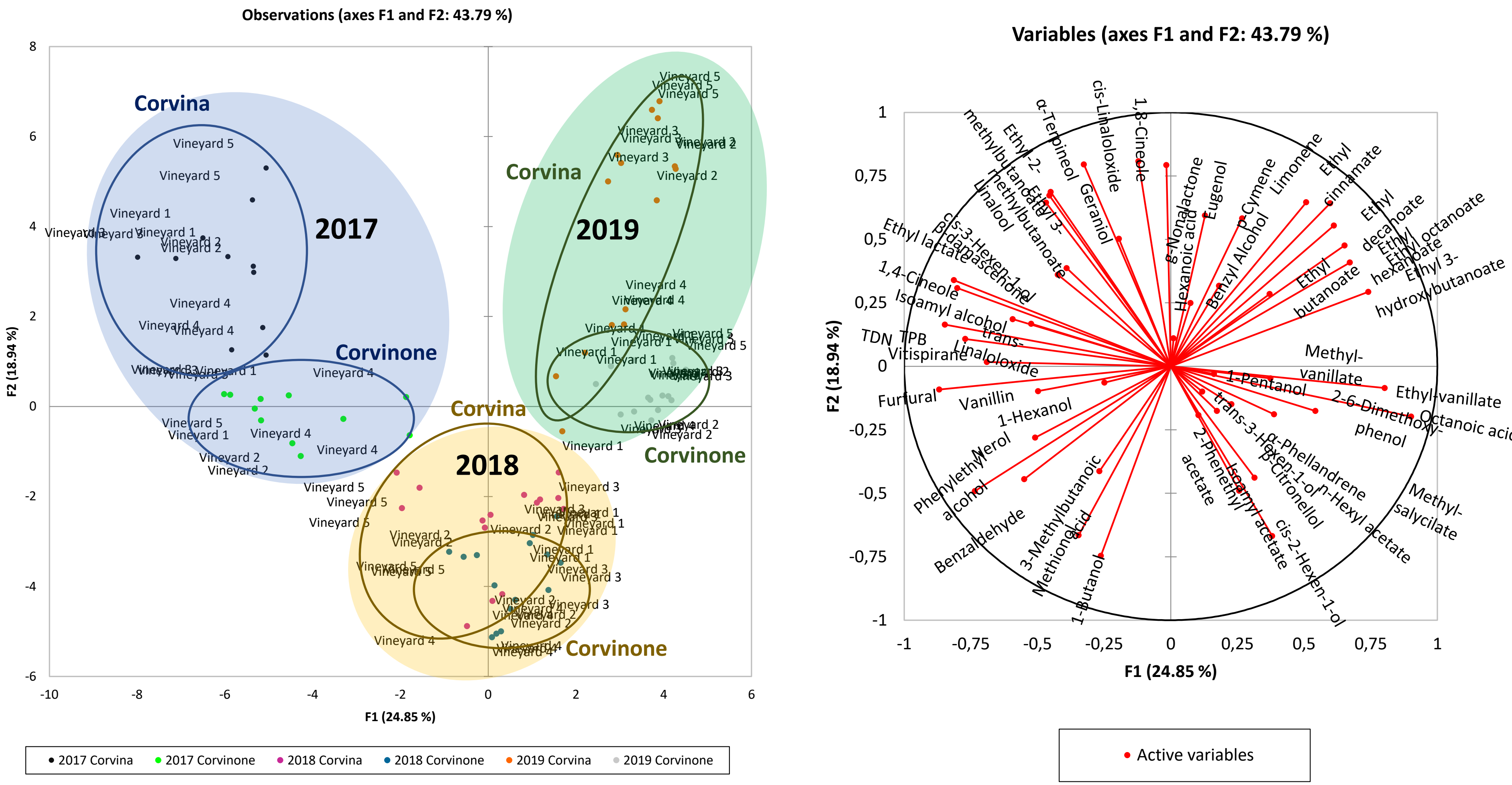


Figure 1.3.1.1. PCA analysis of all fresh grape wines with significantly different compounds. Circles in observations plot are not the result of statistical processing but are useful for a better understanding of the plot

1.3.1.3. Varietal volatile patterns in Corvina and Corvinone

Variety was another important factor responsible for major differences in the sample set, with Corvina and Corvinone wines showing substantial differences in volatile composition. Among analysed compounds, twenty-eight compounds exhibited statistically significant differences in the 2017 vintage, twenty-nine in the 2018 and thirty-two in the 2019 (**Appendix 1.3.1.4**). For a better visualisation of the metabolomic differences between the two varieties, prior to multivariate analysis, independent data rescaling (from 0 to 100) was applied to the wines of each vintage. PCA analyses of the wines of the three vintages, performed on volatiles showing significant differences among samples, indicated that 46.38% of the total variance was explained with the first two principal components, with PC1 and PC2 accounting for 30.38% and 16% of the explained variance respectively (**Figure 1.3.1.2)**. Corvina and Corvinone wines were clearly differentiated on PC1, where all the Corvina wines showed positive values and all Corvinone wines showed negative values. PC2 was associated with a more complex sample segmentation which accounted for both vintage and vineyard influence, which will be discussed in the following sections.

One major element of distinction between Corvina and Corvinone wines was associated with terpene content, which was higher in Corvina wines (**Appendix 1.3.1.4**). Total terpene levels in Corvina wines ranged between 28.1 µg/L and 98.3 µg/L (**Appendix 1.3.1.5**), which is relatively high also compared to other data reported in the literature for other red young wines (Black, *et al*., 2015) (Ferreira, *et al*., 2000). Linalool in particular, in Corvina wines, was often above its Odor Threshold (OT), suggesting that it could be a key compound for the metabolic and sensory discrimination of the two varieties. On the other hand, Corvinone wines showed an average higher content of norisoprenoids in all three years, with values in the range 1.91 – 43.44 µg/L, with differences of particular relevance in the case of β-damascenone and vitispirane.

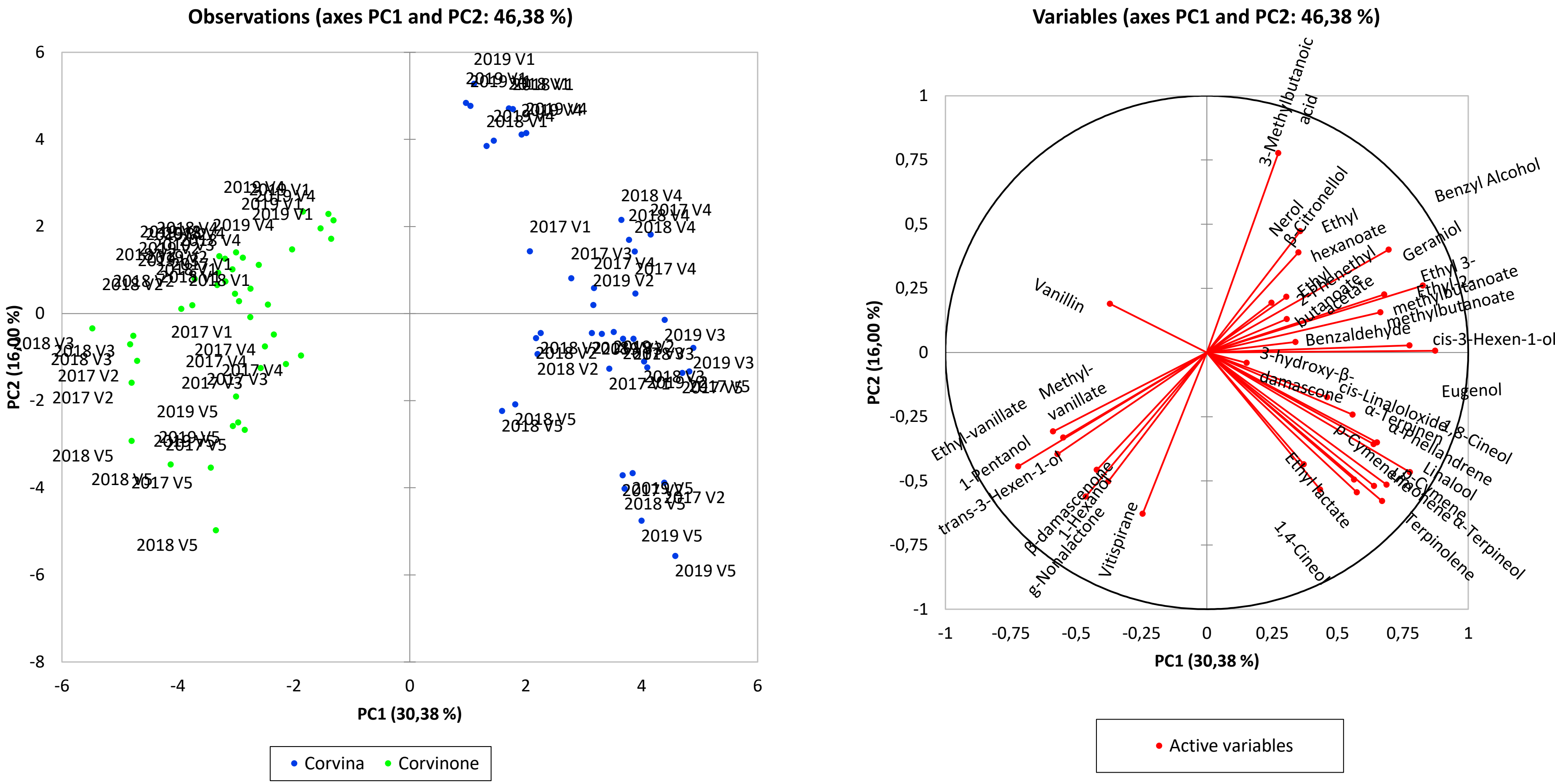


Figure 1.3.1.2. PCA analysis of all studied fresh grapes wines performed with significant different compounds between varieties

C_6 alcohol during this study were another element of varietal distinction as reported in literature (Rapp, *et al.*, 1993) (Oliveira, *et al*., 2006) (Vilanova, *et al.*, 2013). These compounds, which helped to distinguish wines from a metabolic point of view, did not reach the OT. Corvinone was richer of all C_6 alcohols but Corvina wines were much richer of the only one, namely cis-3-hexen-1-ol, which showed higher content than its OT (400 µg/L).

Among the fermentative compounds, the branched-chain fatty acid ethyl esters showed significant differences between Corvina and Corvinone, with Corvina showing an average content up to 2.1-fold higher than Corvinone. Isoamyl acetate (banana aroma) was generally more abundant in Corvina wines. Also, three aromatically active ethyl esters ethyl butanoate, hexanoate and octanoate were more present, even without big differences, in Corvina wines (**Appendix 1.3.1.5**).

In order to gain an insight in the possible sensory implications of these varietal components of Corvina and Corvinone wines, aromatic series were developed for the two wines (Sánchez-Palomo, *et al*., 2019). The odor activity value (OAV) of each compound was calculated dividing the content of each volatile compound by its odor threshold, then compounds were grouped into aromatic series according to their odor descriptor. The OAV were summed to give the intensity for each series. Due to the difficulty to define the specific olfactory contribution of each compound (Zea, *et al*., 2007), some volatile compounds have been assigned into more than one aromatic series (**Table 1.3.1** and **Appendix 1.3.1.6**). Eight series were formed, as described by Sánchez-Palomo *et al*., (2019) with slight modification, namely vinous, fruity, red fruit, evolutive-tobacco, green, spicy, floral and balsamic. The "fatty" and "sweet" series proposed by Sánchez-Palomo *et al*., (2019) were replaced by "vinous", including alcohols, fatty acids and esters. "Fruity" series included esters, β-damascenone and γ-nonalactone. Red fruit series included branched-chain fatty acid ethyl esters. The "Tobacco-evolutive" series included norisoprenoids except vitispirane. The "green" series included C_6 alcohols and isoamyl alcohol. "Spicy series" was composed by ethyl cinnamate and benzenoids, except methyl salicylate. The "floral" series was composed by terpenes (except 1,4- and 1,8-cineole), methyl salicylate, ethyl cinnamate, 2-phenethyl acetate and phenylethyl alcohol. The "balsamic" series was formed by cyclic terpenes, methyl salicylate and vitispirane.

Table 1.3.1. Composition of aromatic series

Vinous	Fruity	Red fruit	Floral	Green	Spicy	Balsamic	Tobacco - evolutive
1-Butanol	Isoamyl acetate	Ethyl-2-methylbutanoate	Phenylethyl alcohol	1-Hexanol	Ethyl cinnamate	α-Terpineol	β-Damascenone
Isoamyl alcohol	n-Hexyl acetate	Ethyl-3-methylbutanoate	2-Phenethyl acetate	trans-3-Hexen-1-ol	Vitispirane	α-Phellandrene	TPB
1-Pentanol	Ethyl lactate		Ethyl cinnamate	cis-3-Hexen-1-ol	Furfural	1,4-Cineol	TDN
Methionol	Ethyl butanoate		trans-Linaloloxide	cis-2-Hexen-1-ol	Benzaldehyde	1,8-Cineol	
Isoamyl acetate	Ethyl-2-methylbutanoate		cis-Linaloloxide	Isoamyl alcohol	Benzyl Alcohol	Vitispirane	
n-Hexyl acetate	Ethyl-3-methylbutanoate		Linalool		Vanillin	Methyl-salycilate	
Ethyl lactate	Ethyl-3-hydroxybutanoate		α-Terpineol		Methyl-vanillate		
Ethyl butanoate	Ethyl hexanoate		β-Citronellol		Ethyl-vanillate		
Ethyl-2-methylbutanoate	Ethyl octanoate		Geraniol		Eugenol		
Ethyl-3-methylbutanoate	Ethyl decanoate		α-Phellandrene		2,6-Dimethoxy-phenol		
Ethyl-3-hydroxybutanoate	β-damascenone		Limonene				
Ethyl hexanoate	γ-nonalactone		p-Cymene				
Ethyl octanoate			Nerol				
Ethyl decanoate							
3-Methylbutanoic acid							
Hexanoic acid							
Octanoic acid							

All series were found to reach sum of OAVs values higher than 1, except for the balsamic series.

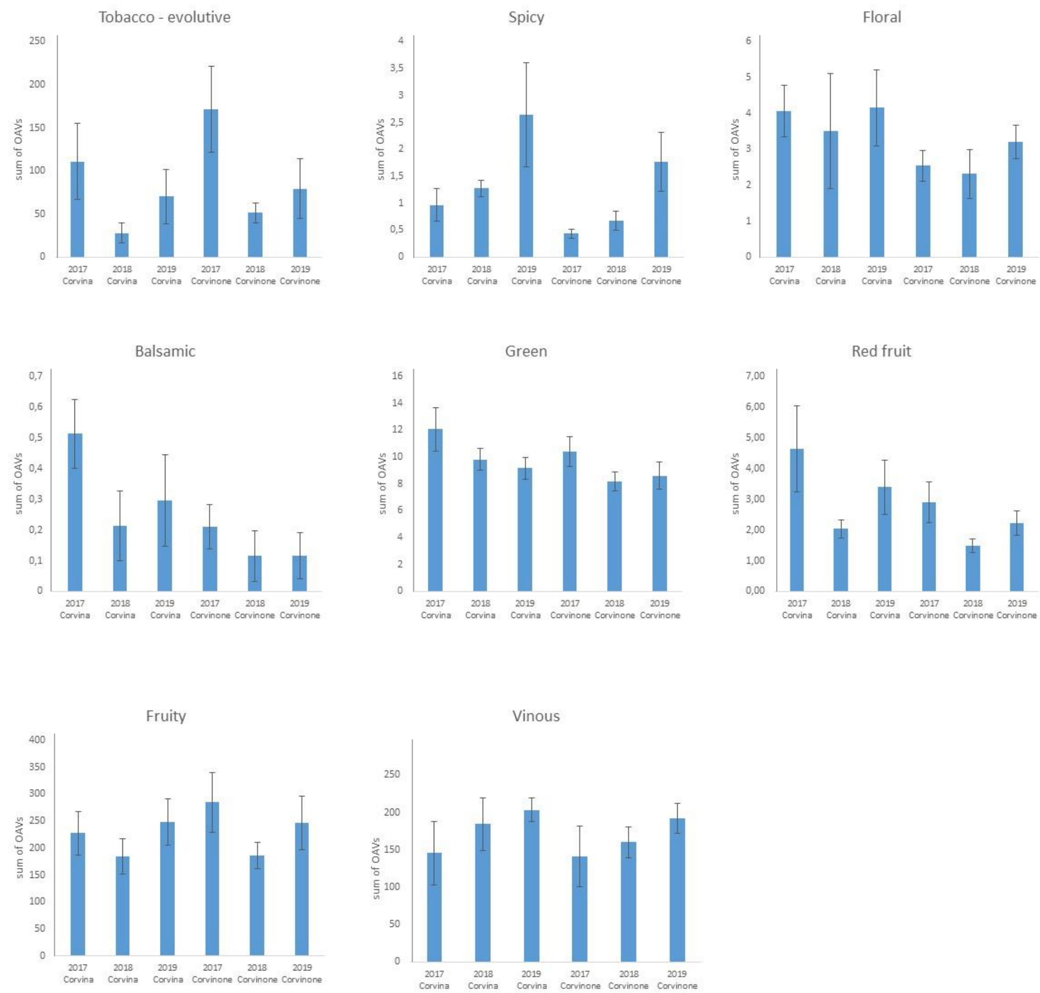


Figure 1.3.1.3. Aromatic series (sum of individual OAVs) of different cultivar-vintages combinations.

As showed in **Figure 1.3.1.3** Corvina was characterized high values in several aromatic series. Being the floral series due to terpenes, it is not surprising that Corvina wines were richer. Concerning the green series, although most of the compounds bringing these parameters, specifically C_6 alcohols, were more abundant in Corvinone, these are far away from the OT, while Corvina showed much higher content of cis-3-hexen-1-ol that only in Corvina exceeded the OT (individual compounds OAVs in **Appendix 1.3.1.7**). The spicy series was mainly due to eugenol (cloves), while the contribution of other benzenoids was negligible. In addition, Corvina wines showed higher balsamic parameters even if the sum of OAVs was lower than one. Vinous and fruity parameters showed similar content, slightly higher vinous in Corvina and fruity in

Corvinone. However, in Corvina the individual compounds characterised by fruity parameters with AOVs above 1 were slightly more abundant in Corvina (isoamyl acetate, ethyl butanoate, hexanoate and octanoate). Red fruit parameter, due to branched chain ethyl esters, was higher in Corvina. Corvinone wines, on the other hand, were characterized by higher scores for the tobacco and evolutive series. This parameter was due to norisoprenoids, which were more abundant in Corvinone wines. In this study, large differences between parameters intensity were recorded: vinous, fruity, tobacco-evolutive showed much larger sum of OAVs than the other parameters (**Figure 1.3.1.3**). Nevertheless, in agreement with past findings (Gürbüz, *et al*., 2006) (Sánchez-Palomo, *et al*., 2019), parameters that were less intense marked the major differences. This could be because summing the individual OAVs not considering other compounds present in the wine matrix caused the effect of ignoring possible synergy, suppression and matrix effects that could alter descriptors intensity.

Corvina and Corvinone were confirmed to be grapes capable of producing wine different both from a metabolic and aromatic point of view. In sum, it can be concluded that, of the two varieties investigated in the present study, Corvina was mostly characterized by compounds such as terpenes, branched chain ethyl esters, some of acetic and ethyl esters, cis-3-hexen-1-ol and benzenoids excepts vanillates which based on their respective OAV are potential contributors to fruity, red fruit, green spicy, floral and balsamic aroma attributes. Vice versa, Corvinone wines were mostly characterized by norisoprenoids, above all β-damascenone, vanillates and all C_6 alcohols except cis-3-hexen-1-ol which based on their respective OAV are potential contributors to tobacco and evolutive scents. Difficulty in identifying common traits between wines of the same varieties was due both to vintages effect but also to the wide variations found in the different vineyards. This, which was partly a difficulty in defining the aromatic profile of the two varieties, was also an element of extreme interest when considering grape origin as a variable able to modify the aromatic profile of wines. This initial evaluation will therefore be used in the following sections of the study to evaluate the existence of an aroma signature associated with individual vineyards, for which the two grapes will be treated separately

1.3.1.4. Influence of geographical origin on volatile chemical signature of single vineyard wines

The notion of the uniqueness of individual vineyards or entire wine regions is extremely recurrent in the wine literature in association with supposed existence of specific sensory profiles (mostly aroma) distinguishing the wines from these specific sites or areas (Bramley, 2016). This observation, in large part based on anecdotal evidences, is associated with the concept of *terroir*, a complex notion which, according to the definition of Van Leeuwen and Seguin (2006), has to do with the relationship between the characteristics of an agricultural product (quality, taste, style) and its geographic origin, which might influence these characteristics. Although there are many studies concerning the main factors characterizing the terroirs of the main wine regions (Roullier-Gall, *et al*., 2014a) (López-Rituerto, *et al*., 2012) (Reynolds, *et al*., 2013) (Cugnetto, *et al*., 2014), the idea that such characteristics can systematically lead to wines with chemical and/or sensory features remains challenging to address. Moreover, significant geo-climatic variability exists within a given wine region and often even within single vineyard parcels (Bramley, 2016). In addition to the notion of terroir the one of 'cru' is often mentioned, in particular at the level of individual producers. The term cru refers to a single vineyard providing grapes able to systematically produce wines with distinctive and recognizable characteristics. As such, cru vineyards are often selected for the production of single vineyard wines, made with grapes coming from the most part if not entirely from such unique vineyard parcels. In spite of its commercial importance, identification of cru vineyards and allocation of their grapes to specific high end wine segments is mostly based on *a priori* and often anecdotal knowledge and tasting of grapes and wines. Conversely, the chemical markers of such unique characteristics remain largely unknown. One central objective of this work was to establish to which extend and by which chemical markers wines produced with grapes of individual vineyards (a.k.a single vineyards wines or cru wines) could be distinguished based on a volatile chemical signature, beyond the obvious influence of major environmental factors, in particular the climatic conditions specific of each vintage.

The data presented in the previous section (**Figures 1.3.1.1** and **1.3.1.2**) indicated however that considerable variations in the composition of the aroma signatures of the wines was due to vintage and variety. For this reason, it was decided to treat the data concerning the two varieties separately, so that possible markers of Valpolicella single-vineyard wines could be searched within each specific variety.

PCA carried out on the volatile data of each separate vintage indicated that, for both Corvina and Corvinone, the vineyard had a marked impact on the volatile chemical signatures of the wines (**Figures 1.3.1.4** and **1.3.1.5**). This observation is in line with previously published data concerning the variability in wine volatile composition in relationship to grape origin (Robinson, *et al*., 2014) (Antalick, *et al*., 2015) (Bramley, 2016) (Slaghenaufi, *et al*., 2019), and supports the view that grape origin can be a major source of volatile diversity even within the same variety, and in some cases even within contiguous vineyard blocks, as in the case of V1-V3.

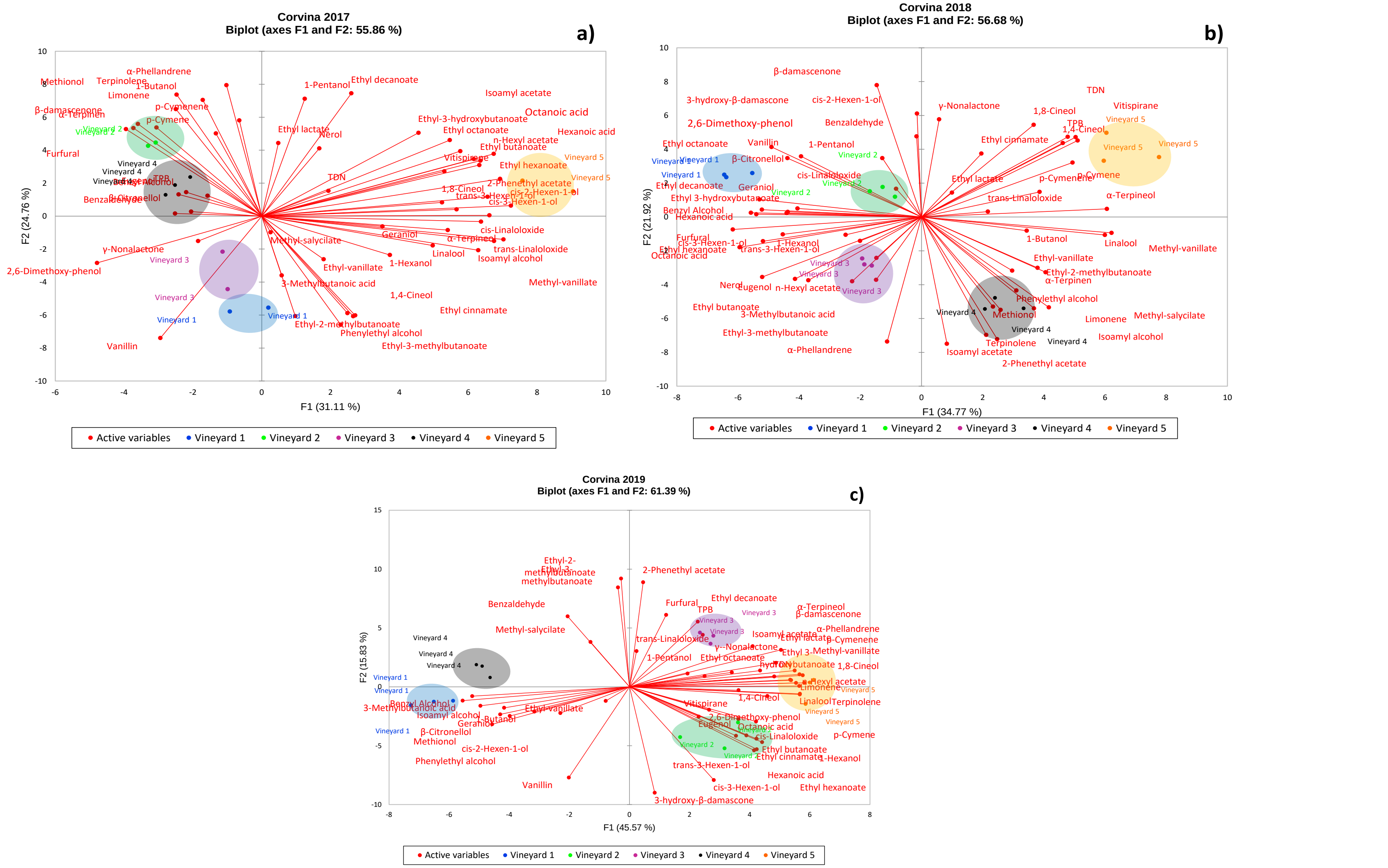


Figure 1.3.1.4. PCA analysis of a) 2017 b) 2018 and c) 2019 fresh Corvina wines. Circles are not the result of statistical processing but are useful for a better understanding of the plot

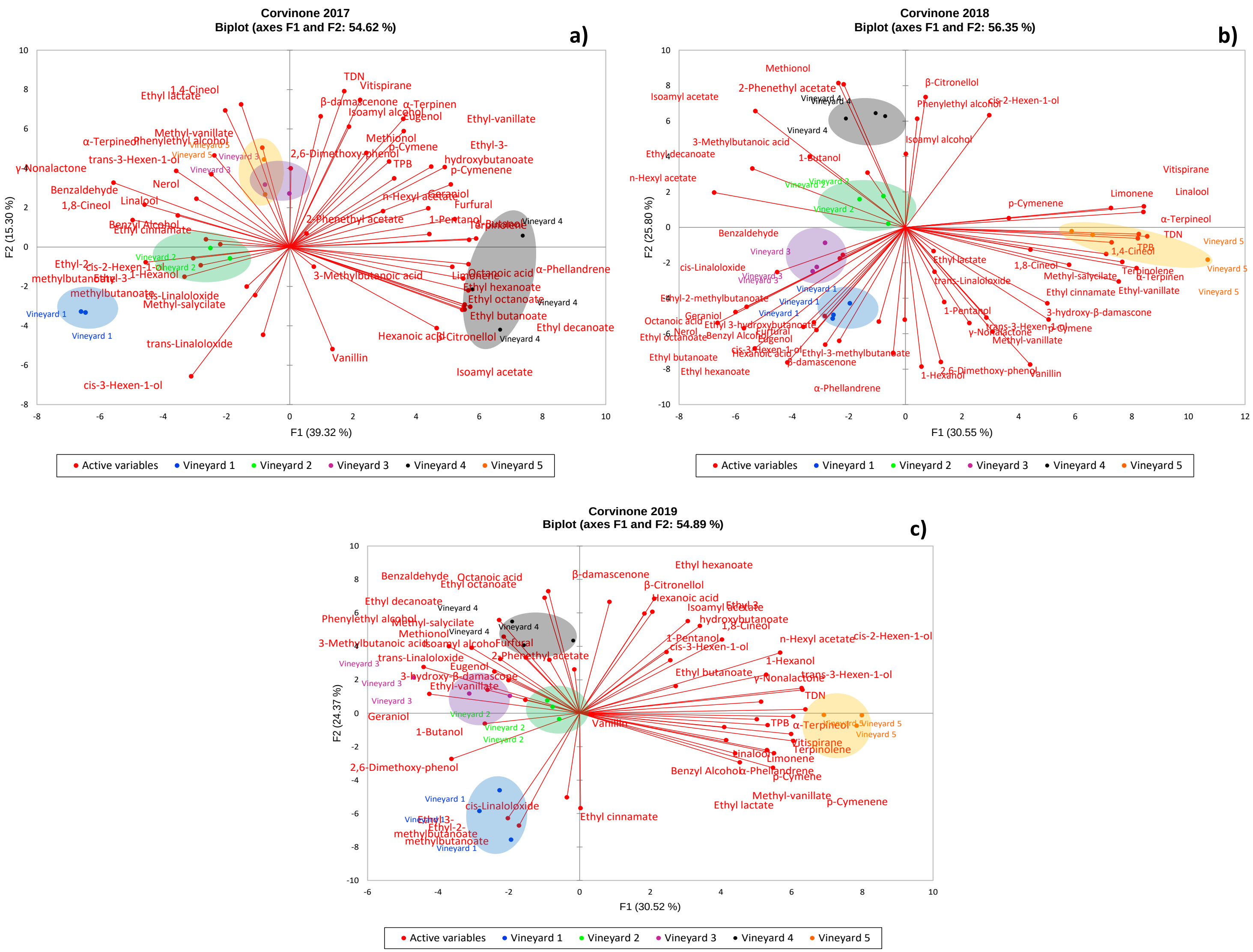


Figure 1.3.1.5. PCA analysis of a) 2017 b) 2018 and c) 2019 fresh Corvinone wines. Circles are not the result of statistical processing but are useful for a better understanding of the plot

However, because of the large quantitative differences due to vintage (**Figure 1.3.1.1**), it was difficult to observe clear patterns indicating the existence of an aroma signature that characterized systematically the volatile composition of wines obtained from each vineyard (composition data in **Appendix 1.3.1.8-1.3.1.13**). The variability associated to vintage posed indeed a crucial issue, as our goal was to be able to identify specific markers of the identity of wines from individual vineyard, beyond the variability due to the characteristics of each vintage. Nevertheless, some recurring associations could be observed. For example, in the case of Corvina wines, V5 was often associated with linalool and other monoterpenes, TDN and vitispirane, V1 and V3 with ethyl-2 and ethyl-3-methylbutanoate and vanillin. Likewise, for Corvinone wines, wines from V4 were often associated with β-citronellol, isoamyl acetate and 2-phenethyl acetate, and V5 was associated with monoterpenes, TPB and TDN. Depending on the vintage and on the vineyard of grape origin, variations in the concentrations of several compounds were is some cases rather large, as for example for grape derived compounds such as linalool, α-terpineol, β-citronellol, β-damascenone, vitispirane. Significant differences were also observed for ester such as isoamyl acetate, which is almost entirely derived from yeast metabolism. Considering that Corvina and Corvinone are non-aromatic grape varieties in which grape-derived compounds are present in the form of precursors that are released during the vinification process, differences in grape-derived compounds are likely to indicate variations in precursors content of the grapes at harvest (Slaghenaufi, *et al*., 2019). However, as in wines from non-aromatic grapes, compounds such as linalool, β-citronellol, and β-damascenone are in large part due to yeast-driven release from glycosidic precursor (Ugliano, *et a*l., 2010) (Lloyd, *et al*., 2011), it is also possible that grapes from different origin and therefore composition induce different metabolic response in yeast. The existence of such more complex influence is also supported by the large variations observed for fermentation-derived compounds such as isoamyl acetate, clearly indicating the existence of complex interactions between grape composition and origin and yeast behaviour. These aspects will be discussed more in detail later in this thesis. In consideration of the complexity of the different patterns observed, in particular in relationship to the influence of vintage, in order to overcome vintage variations, it was decided to apply, before multivariate analysis, a preliminary data treatment strategy. Data of each vintage have been rescaled from 0 to 100, and then aggregated into a single matrix. PCAs were performed with significant different compounds between vineyards (**Appendix 1.3.1.14** and **1.3.1.15**).

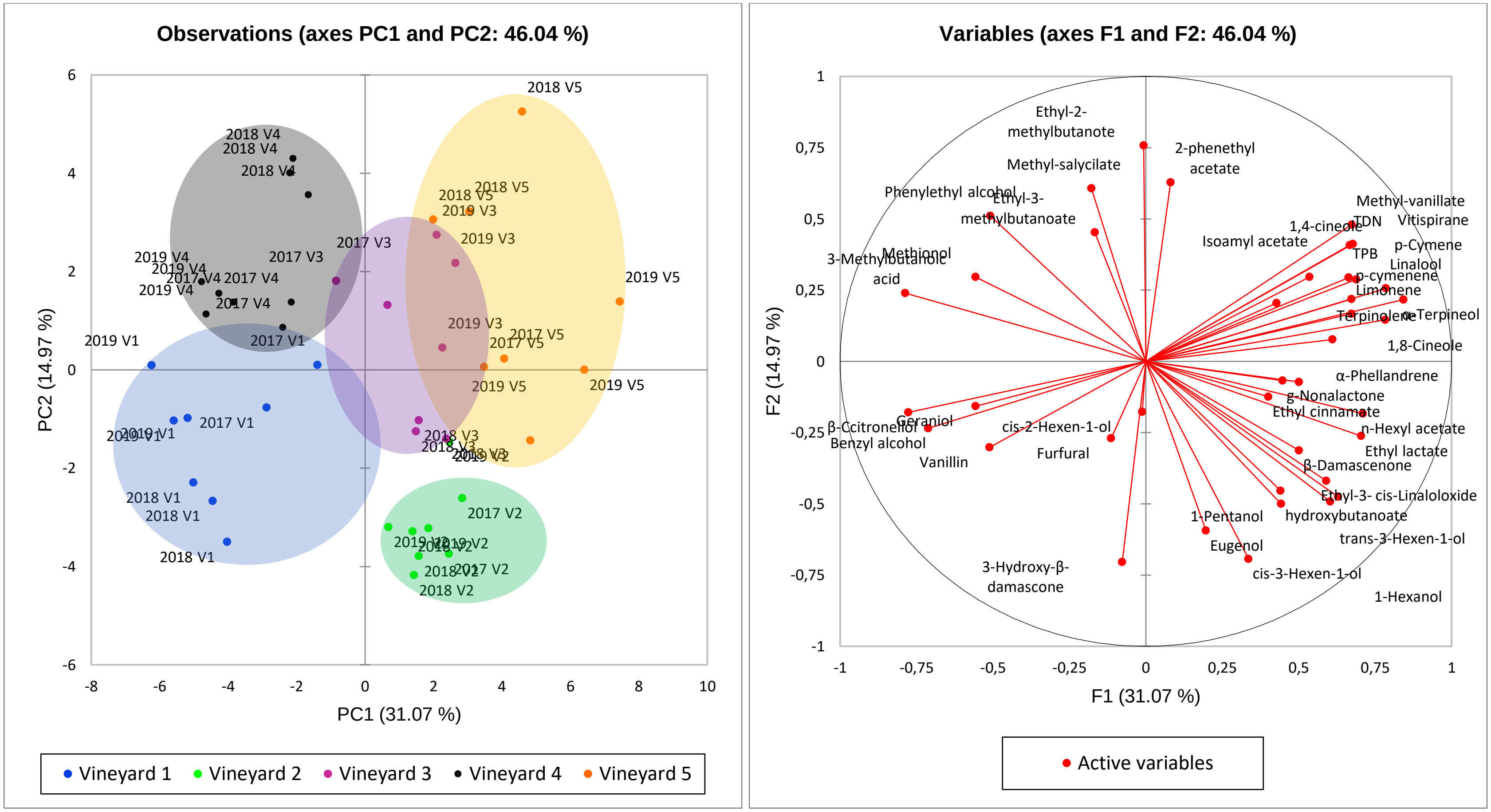


Figure 1.3.1.6. PCA analysis of Corvina wines from fresh grapes with significantly different volatile compounds after rescaling (from 0 to100). 2017-2019 refers to vintages V1-V5 refers to vineyard 1-vineyard 5. Circles are not the result of statistical processing but are useful for a better understanding of the plot

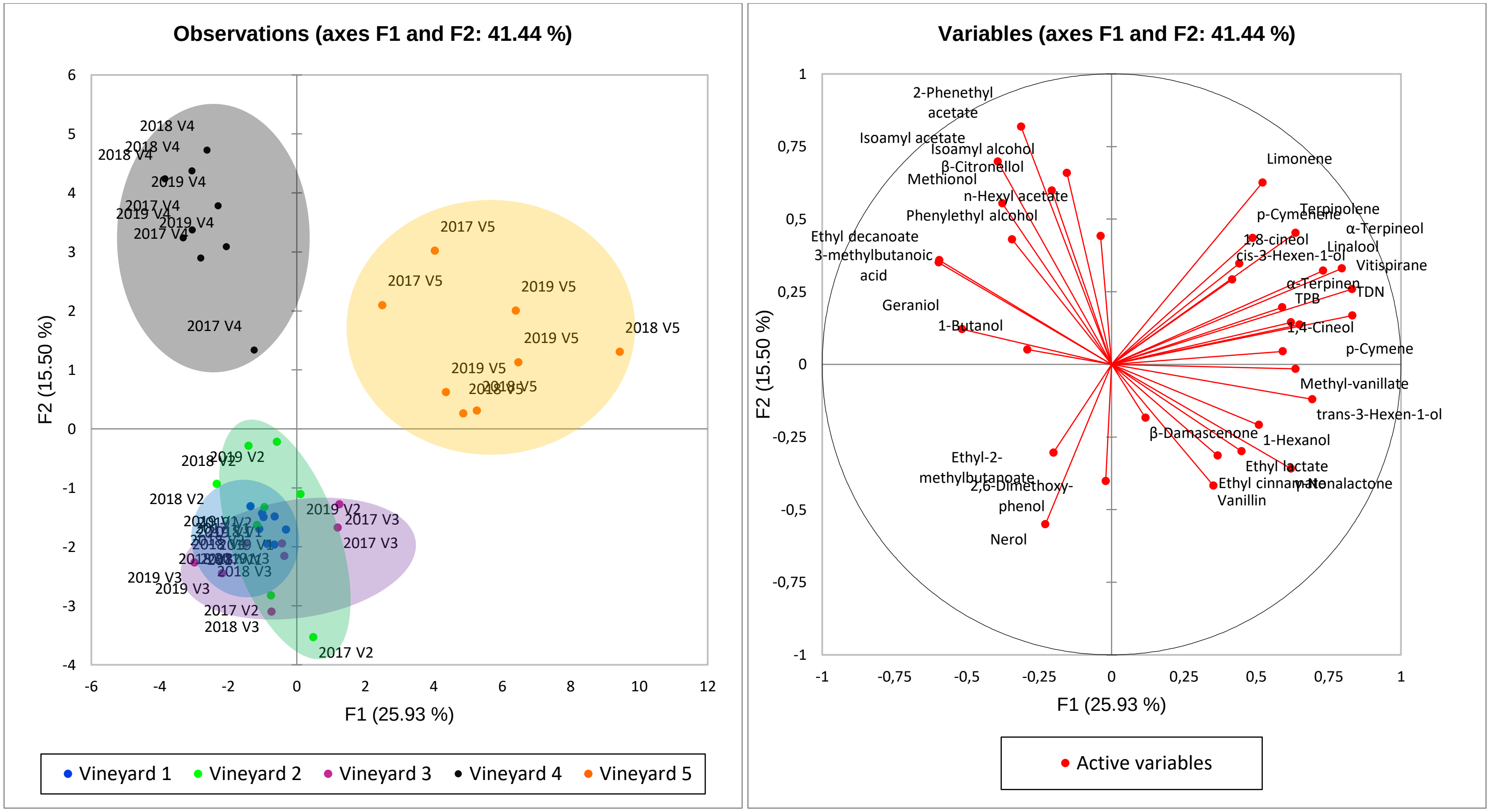


Figure 1.3.1.7. PCA analysis of Corvinone wines from fresh grapes with significantly different volatile compounds after (from 0 to100). 2017-2019 refers to vintages V1-V5 refers to vineyard 1-vineyard 5. Circles are not the result of statistical processing but are useful for a better understanding of the plot

This approach allowed to ‘isolate’ the actual contribution of vineyard of grape origin, providing a clear evidence for the existence, in the finished wines, of patterns of volatile compounds that can be uniquely associated with the vineyard of grape origin for both Corvina and Corvinone. (**Figures 1.3.1.6** and **1.3.1.7**). We define these patterns ‘aroma chemical signatures’ of geographical origin, as they encompass the volatile compounds making unique each single vineyard wine. As it can be observed, both for Corvina and Corvinone wines from the same vineyards were clustered together regardless of the vintages, with clusters being sufficiently well separated using only the two principal components. This was particularly true for Corvina, where specific aroma chemical signatures could be observed for each vineyard site, whereas in the case of Corvinone, V1-V3, all belonging to the estate located in the Mezzane valley, were grouped together.

Hierarchical Cluster Analysis was performed using the same compounds of the multivariate analysis. The results of this analysis are shown in **Figure 1.3.1.8** for both Corvina and Corvinone. In all cases wines from the same vineyard are clustered together apart from V3 2017 Corvina. In Corvina three clusters were formed, the first comprising V1 and V4, the second V2 and the third V3 and V5. Interestingly within Clusters 1 and 3 sub-clusters associated with individual vineyards were observed. Also, in Corvinone, 3 clusters were formed which coincide perfectly with those previously described by PCA, thus a first cluster formed by V5, a second by V4 and a last one by V1, V2 and V3.

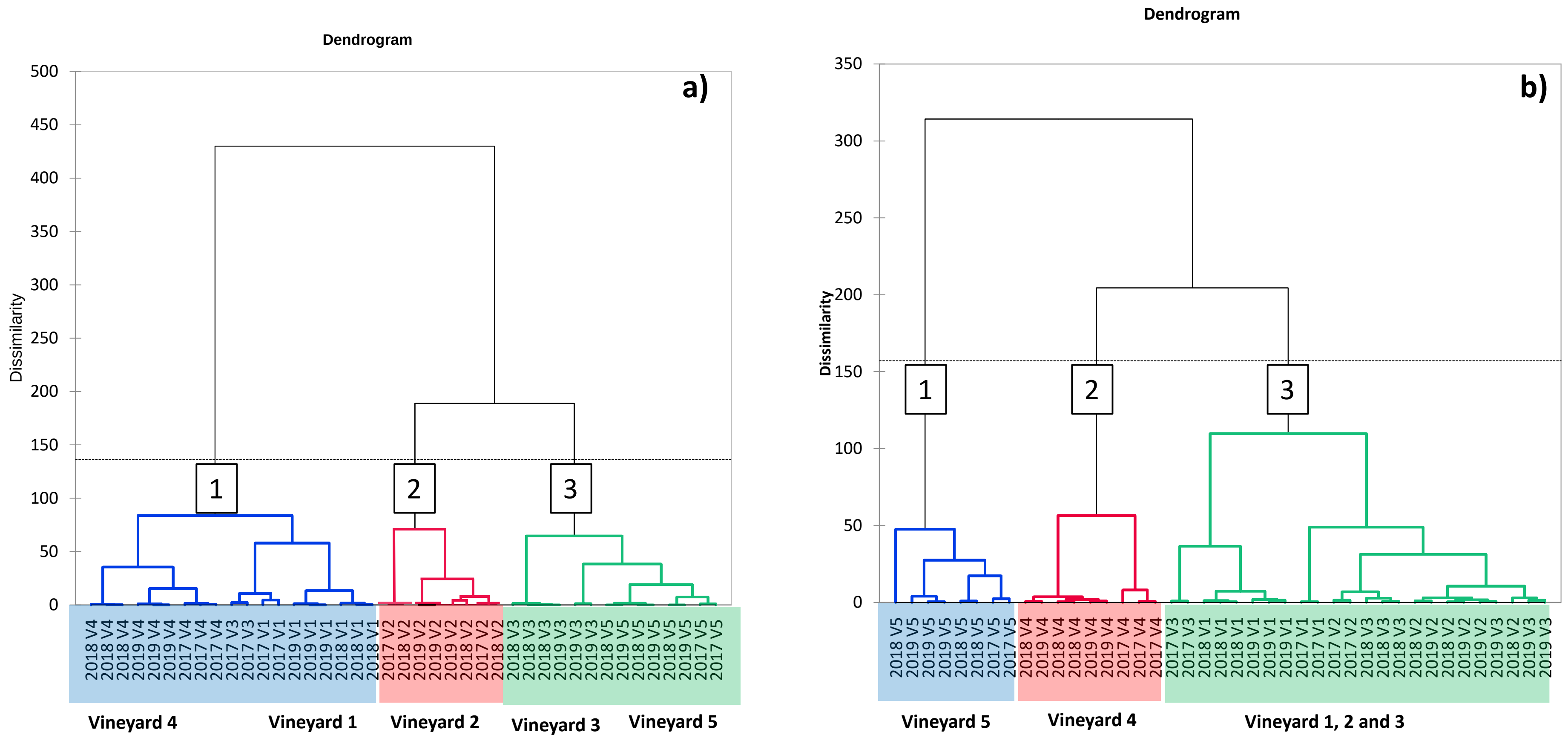


Figure 1.3.1.8. HCA analysis of chemical data of fresh a) Corvina and b) Corvinone wines

Terpenes and norisoprenoids were two classes on volatile compounds having a particularly strong influence in determining aroma chemical signatures of the different single vineyard wines. Concentration values of total terpenes and norisoprenoids as well as different terpenes and norisoprenoids in the various wines are shown in **Figures 1.3.1.9-1.3.1.11**

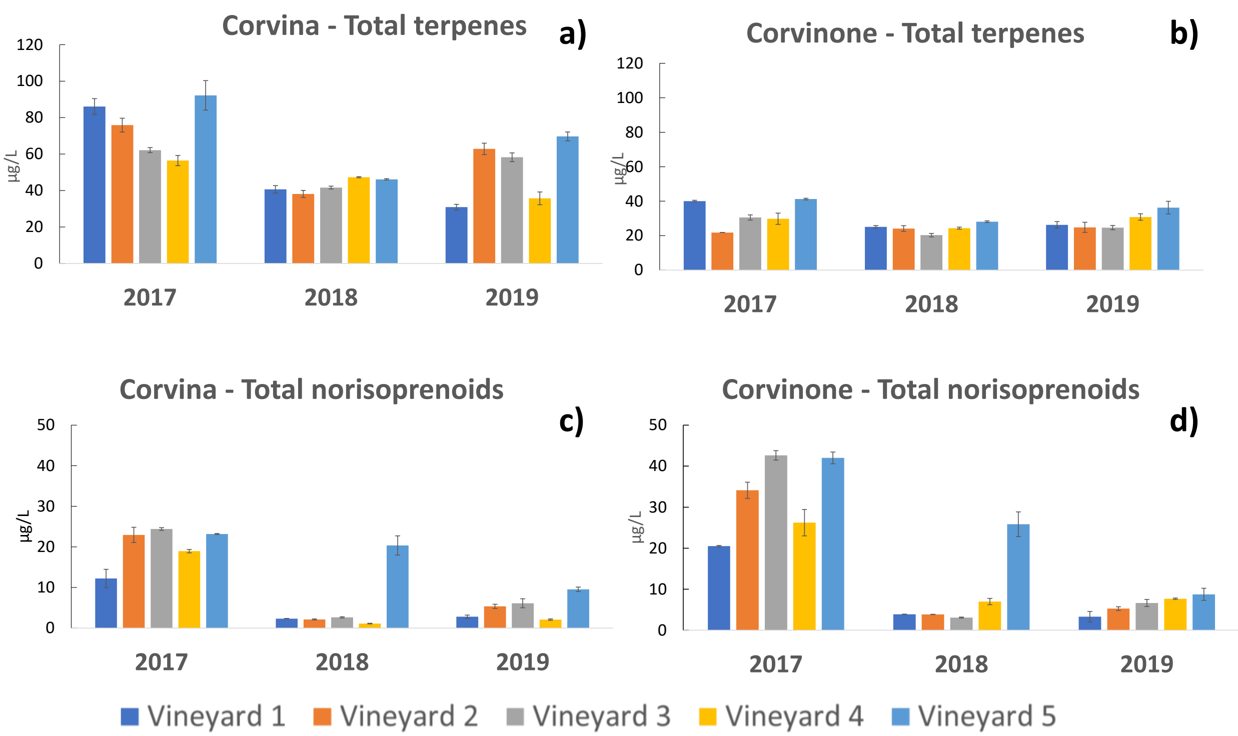
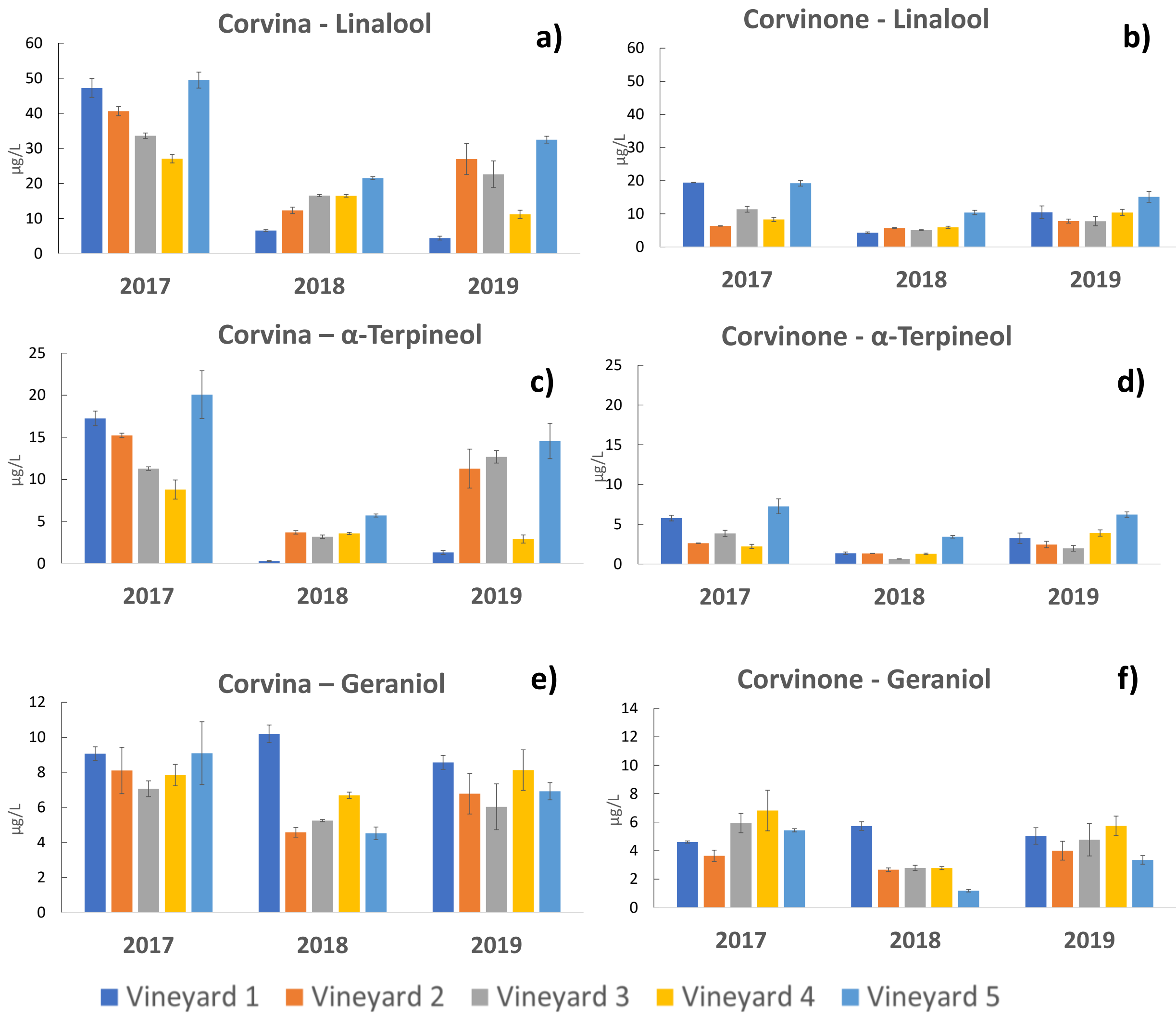


Figure 1.3.1.9. Content of a) Corvina total terpenes b) Corvinone total terpenes c) Corvina total norisoprenoids d) Corvinone total norisoprenoids.

Linalool was the most abundant terpene and, depending on the vintage, attained concentrations higher than 50 µg/L, higher than the reported odor threshold of 25 µg/L (Lopez, *et al.*, 2002). Corvina wines were generally richer in terpenes compared to Corvinone. Also, worth observing that the high levels of linalool in Corvina wines are much higher than those commonly observed in red wine (Black, *et al.*, 2015), suggesting that linalool could be an important aroma contributor in Valpolicella wines. β-Damascenone and vitispirane were the most abundant norisoprenoids, the former attaining concentrations largely exceeding its reported odor threshold of 0.05 µg/L (Francis, *et al.*, 2005).



Corvina - Linalool
a)
Corvinone - Linalool
b)
Corvina – α-Terpineol
c)
Corvinone - α-Terpineol
d)
Corvina – Geraniol
e)
Corvinone - Geraniol
f)
μg/L
2017
2018
2019
Vineyard 1
Vineyard 2
Vineyard 3
Vineyard 4
Vineyard 5

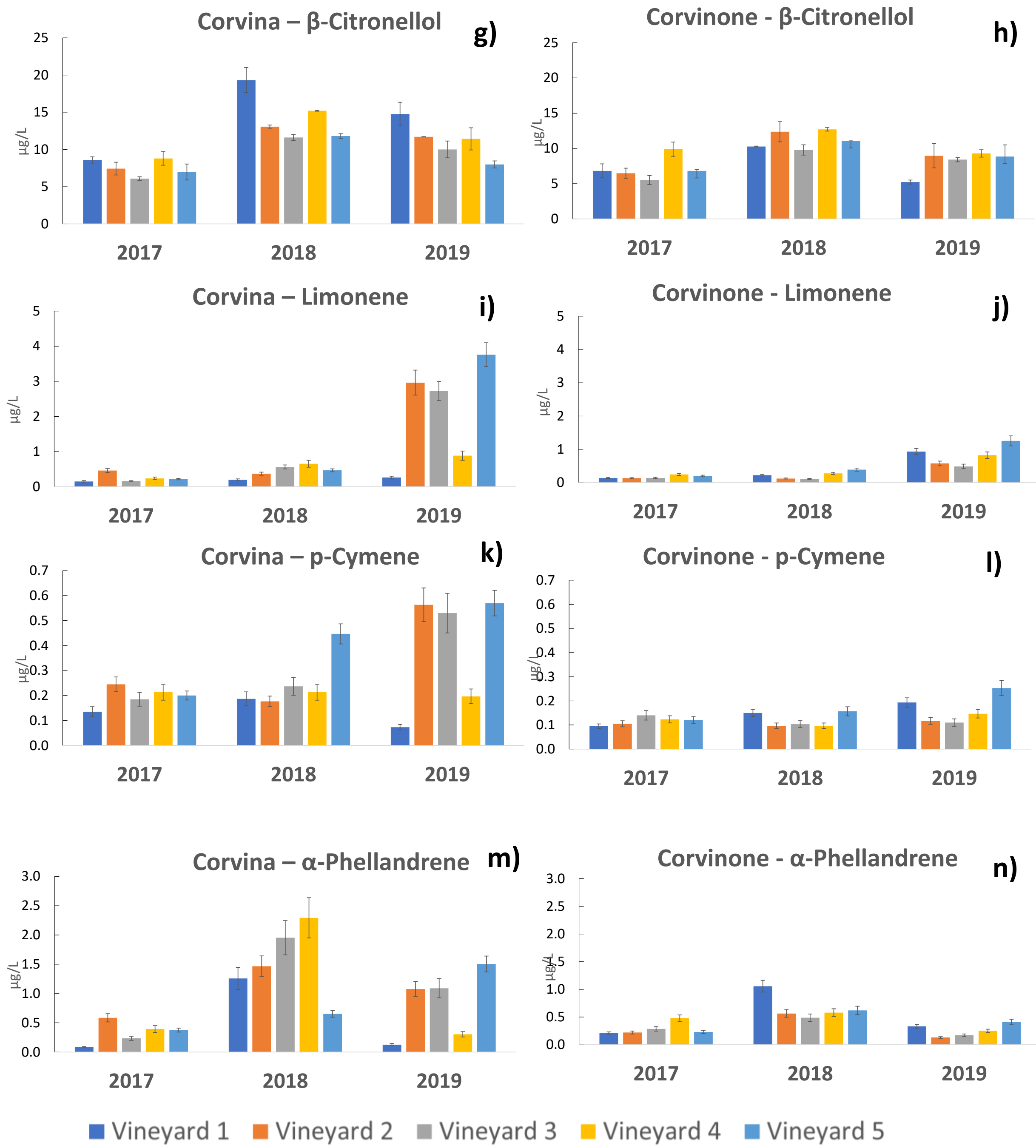


Figure 1.3.1.10. Content of a) Corvina linalool b) Corvinone linalool c) Corvina α-terpineol d) Corvinone α-terpineol e) Corvina geraniol f) Corvinone geraniol g) Corvina β-citronellol h) Corvinone β-citronellol i) Corvina limonene j) Corvinone limonene k) Corvina p-cymene l) Corvinone p-cymene m) Corvina α-phellandrene and n) Corvinone α-phellandrene.

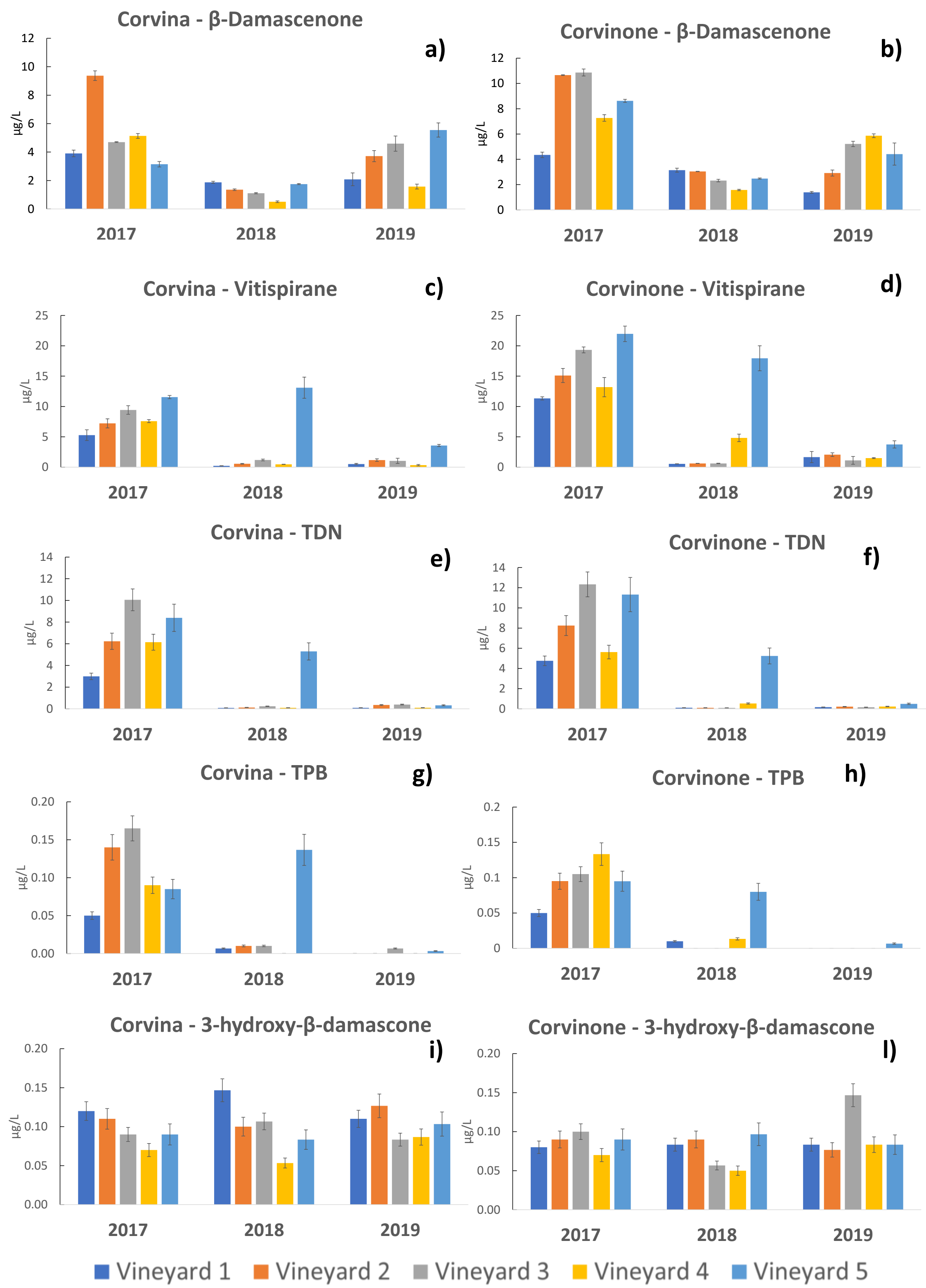


Figure 1.3.1.11. Content of a) Corvina β-damascenone b) Corvinone β-damascenone c) Corvina Vitispirane d) Corvinone Vitispirane e) Corvina TDN f) Corvinone TDN g) Corvina TPB h) Corvinone TPB i) Corvina 3-hydroxy- β-damascone l) Corvinone 3-hydroxy- β-damascone.

An influence of vineyard location in terpenes and norisoprenoids profiles has been already reported, although this was observed mainly across relatively large geographical areas (Wen, *et al*., 2005) (Sabon, *et al*., 2002) (Robinson, *et al*., 2014), and few between adjacent vineyards (Slaghenaufi, *et al*., 2019). Among the factors influencing terpenes and norisoprenoids content, soil composition (Jackson, 2008), sunlight exposure (Belancic, *et al*., 1997), water availability (Koundouras, *et al*., 2006) altitude and temperature could have played a role (Alessandrini, *et al*., 2016). The two weather stations, although not located inside the vineyards, recorded different temperature, in Illasi, August and September had slightly higher temperatures than San Pietro (**Appendix 1.2.1**). Furthermore, the stations recorded different rainfall in the two areas (**Appendix 1.2.2**), and V4 and V5 were much closer to the Garda Lake **(Figure 1.2.1)**, a large water basin that can influence significantly climatic conditions of the area. While all these factors could have contributed to determining the characteristics of each vintage, we report clearly the systematic contribution of certain volatiles to the aroma chemical signatures across multiple vintages rather than their role in differentiating grape origins.

In addition to grape-related compounds such as terpenes and norisoprenoids, fermentative compounds also contributed to the aroma chemical signature of the different geographical origins, in particular esters. Isoamyl acetate, the main acetic esters, was a strong driver of vineyard differentiation in every vintage with concentrations in all cases exceeding the reported threshold of 30µg/L (**Figure 1.3.1.12**).

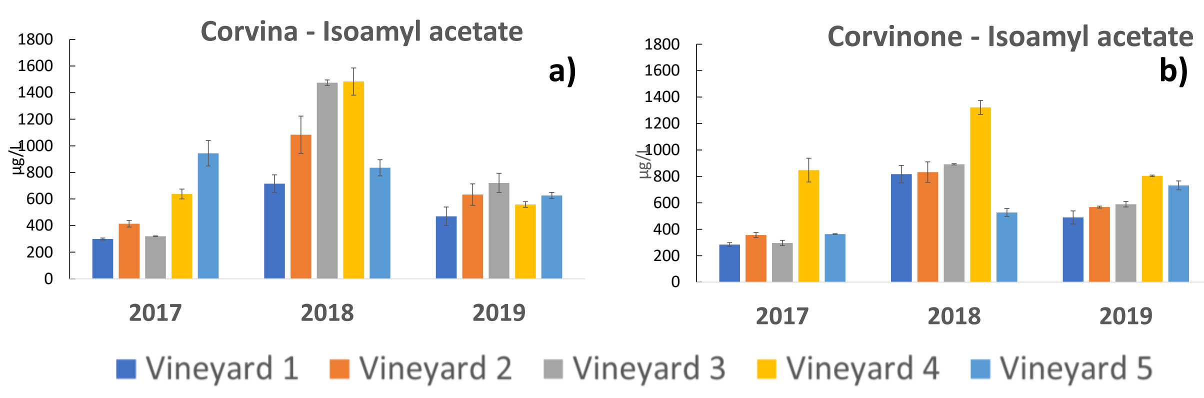


Figure 1.3.1.12. Isoamyl acetate content in a) Corvina and b) Corvinone wines.

Likewise, branched-chain fatty acid ethyl esters contributed to the differences in aroma signatures. Conversely, ethyl esters, potent odorants with fruity notes, although varying to a significant extent across wines in relation to vineyard of origin (**Figure 1.3.1.13**), did not show any clear patterns associated with the clustering of **Figures 1.3.1.7** and **1.3.1.8**

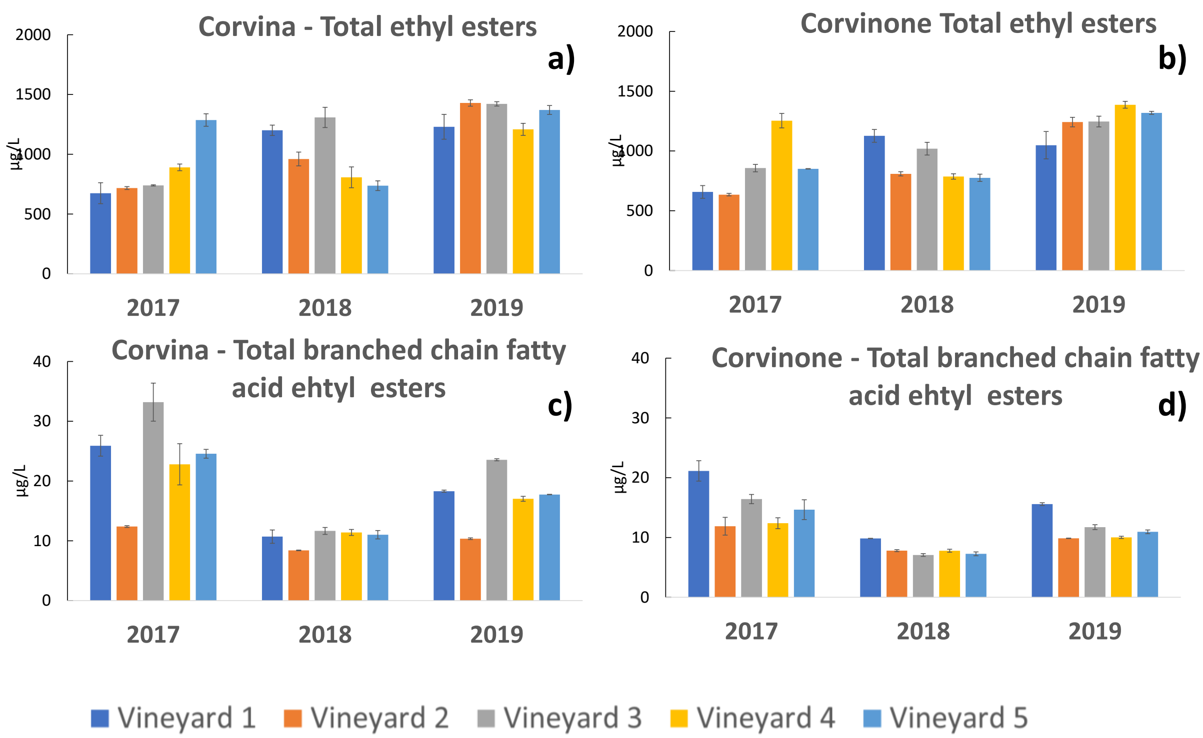


Figure 1.3.1.13. Content of a) Corvina total ethyl esters b) Corvinone total ethyl esters c) Corvina total branched chain fatty acid ethyl esters d) Corvinone total branched chain fatty acid ethyl esters.

The observation that esters of fermentative origin contributed to geographically defined aroma chemical signatures was somewhat surprising. On one hand, it is implicit that variations in grape must compositionally features, in particular yeast nutrients such as sugars and nitrogen, could result in difference in production of fermentative compounds (Ugliano, *et al*., 2009). On the other hand, once again the observation of repeated patterns suggests the existence of specific features that could be, in turn, drivers of identity and typicality of individual vineyards. Some of these relationships will be explored later in this thesis (cfr section "**Grape compositional features determining wine aroma signatures**").

In **Table 1.3.2** correlations between the content of volatile compounds between Corvina and Corvinone of the same vintage are shown. Of great interest was the observation that, for several compounds, vineyard-related patterns were very well correlated between the two varieties.

Table 1.3.2. Coefficients of correlation between Corvina and Corvinone volatile compounds of the same vintage

Compound	R^2	Compound	R^2
1-Butanol	**0.813**	cis-Linaloloxide	**0.376**
Isoamyl alcohol	**0.767**	trans-Linaloloxide	**0.447**
1-Pentanol	0.249	Linalool	**0.472**
Phenylethyl alcohol	**0.597**	α-Terpineol	**0.480**
Methionol	**0.645**	β-Citronellol	0.268
1-Hexanol	**0.434**	Geraniol	**0.540**
trans-3-Hexen-1-ol	0.252	α-Phellandrene	0.201
cis-3-Hexen-1-ol	0.326	α-Terpinen	**0.480**
cis-2-hexen-1-ol	**0.386**	1,4-Cineole	0.243
Isoamyl acetate	**0.504**	Limonene	**0.431**
2-phenethyl acetate	**0.351**	1,8-Cineole	0.190
n-Hexyl acetate	0.087	p-Cymene	0.151
Ethyl 2-methylbutanoate	**0.505**	Terpinolene	**0.380**
Ethyl 3-methylbutanoate	**0.632**	Nerol	0.335
Ethyl lactate	**0.665**	p-Cymenene	0.079
Ethyl butanoate	0.073	β-Damascenone	**0.513**
Ethyl 3-hydroxybutanoate	**0.390**	3-Hydroxy-β-damascone	0.000
Ethyl hexanoate	**0.455**	Vitispirane	**0.918**
Ethyl octanoate	**0.540**	TPB	**0.473**
Ethyl decanoate	**0.595**	TDN	**0.758**
Ethyl cinnamate	**0.745**	Furfural	**0.917**
3-Methylbutanoic acid	**0.532**	Benzaldehyde	**0.960**
Hexanoic acid	0.209	Benzyl Alcohol	0.267
Octanoic acid	**0.872**	Vanillin	0.311
		Methyl vanillate	0.304
		Ethyl vanillate	**0.584**
		Methyl salycilate	0.265
		2-6-Dimethoxyphenol	**0.361**
		Eugenol	0.001
		γ-Nonalactone	**0.386**

Bold values show significant correlation (Pearson. α=0.05)

This was the case for norisoprenoids such as vitispirane, damascenone, and TDN, several terpenes, some benzenoids as well as a number of esters (the trends of some of these compounds can be seen in **Figures 1.3.1.9-1.3.1.13**). This indicate clearly that, while variety influenced strongly the actual concentration of certain compounds, the way in which these same compounds varied across different vineyards was only in part affected by the variety, and much more by the vineyard itself. It is worth observing that Corvina and Corvinone are genetically related (Cipriani, *et al*., 2010), whereas others, genetically more distant grape varieties could show greater differences in their response. Nevertheless, the existence of such relationships strongly supports the view that, within the conditions of each vintage, each vineyard site determines unique characteristics leading to specific wine compositional patterns that can be common to different varieties when site and production practices are the same.

Altogether, the observations gathered in this section of the work clearly indicate that a specific aroma chemical signature can be attributed to wines coming from individual vineyards, as the composition of their volatile fraction displays patterns that reflect the geographical origin of the grapes. Because of the great influence of vintage on the absolute concentration of individual volatiles, the existence of these aroma signatures does not necessarily imply that a wine from a given vineyard will be always characterized by certain concentrations of a given compound, but that, within the context of each vintage, it will give wines with higher (or lower) concentrations compared to other vineyards.

1.3.1.5. Relationship between aroma chemical signatures and wine sensory identity

One important dimension of identity and typicality lies in the possibility that the aroma chemical signatures that we have observed could also be reflected in the sensory characteristics of the wines. To investigate this aspect, wines of 2018 and 2019 vintages were submitted to sorting task analysis. This approach, based on the evaluation of odor similarities across a range of samples, has been successfully used to establish the existence of odor profiles that can be associated to specific variables, including grape variety, yeast strain, wine quality grade (Sáenz-Navajas, *et al*., 2016) (Alegre, *et al*., 2017) (Alegre, *et al*., 2020). In the present study, we were interested in clarifying whether wines with a defined variety and geographical origin could be grouped in clusters of odor similarities, and whether these reflected to some extent either the geographical origin itself or the aroma chemical signatures that were observed, or combinations thereof. Data of the sorting task were therefore elaborated as dendrograms and then compared with volatile data means of PLS-DA, a supervised multivariate analytical technique, using either raw chemical data (concentration values) or scores of aromatic series as previously developed. The results of the sorting tasks showed that samples could be generally divided in three clusters, each one aggregating samples from one or two different vineyards. Biological replicates were projected close to each other in the dendrogram with only few exceptions (**Figures 1.3.1.13-1.3.1.14)**.

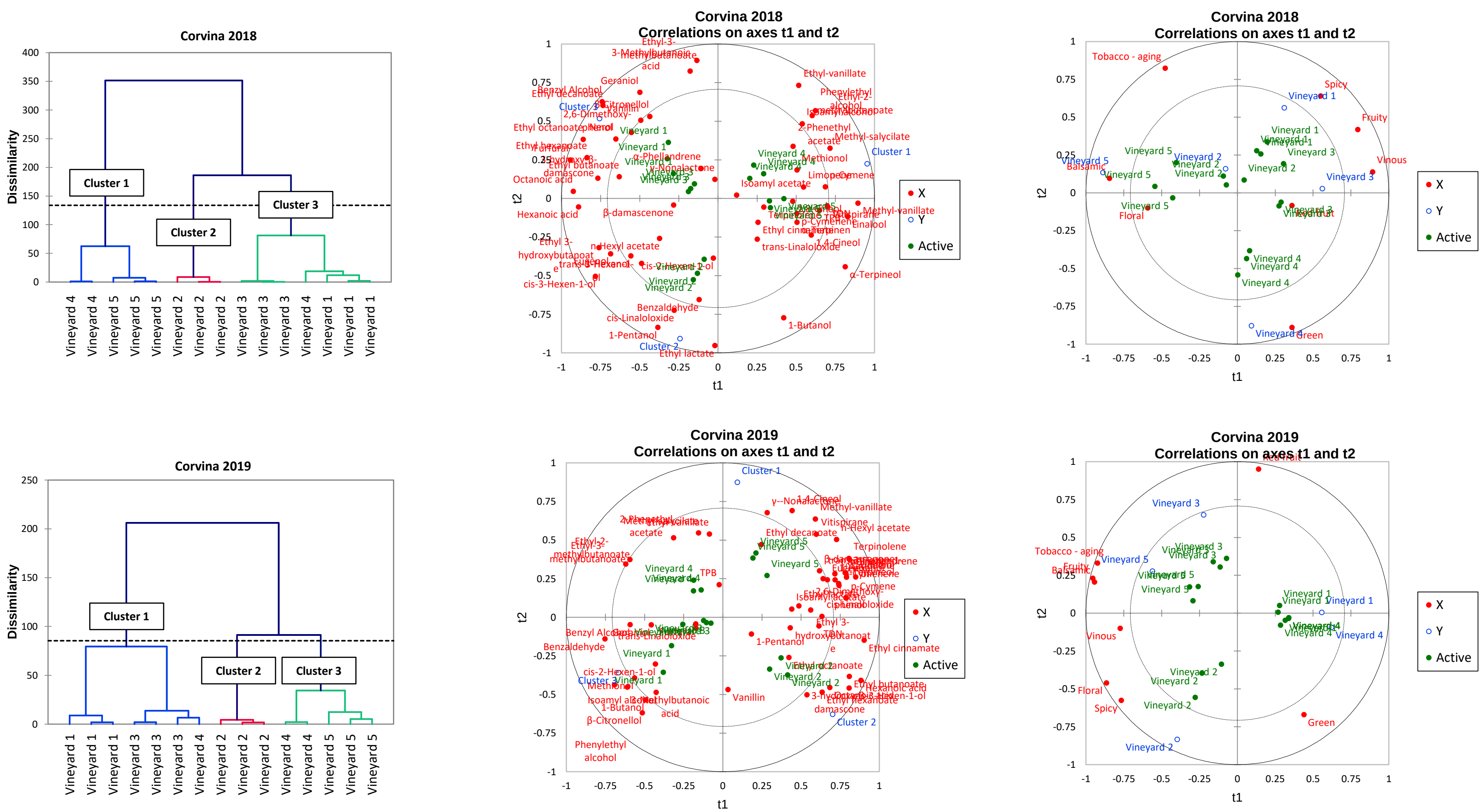


Figure 1.3.1.13. Fresh Corvina 2018 a) HCA of sorting task data b) PLS-DA analysis of volatile chemical data referred to sensory clusters c) PLS-DA of aroma series and fresh Corvina 2019 d) HCA of sorting task data e) PLS-DA analysis of volatile chemical data referred to sensory clusters f) PLS-DA of aroma series

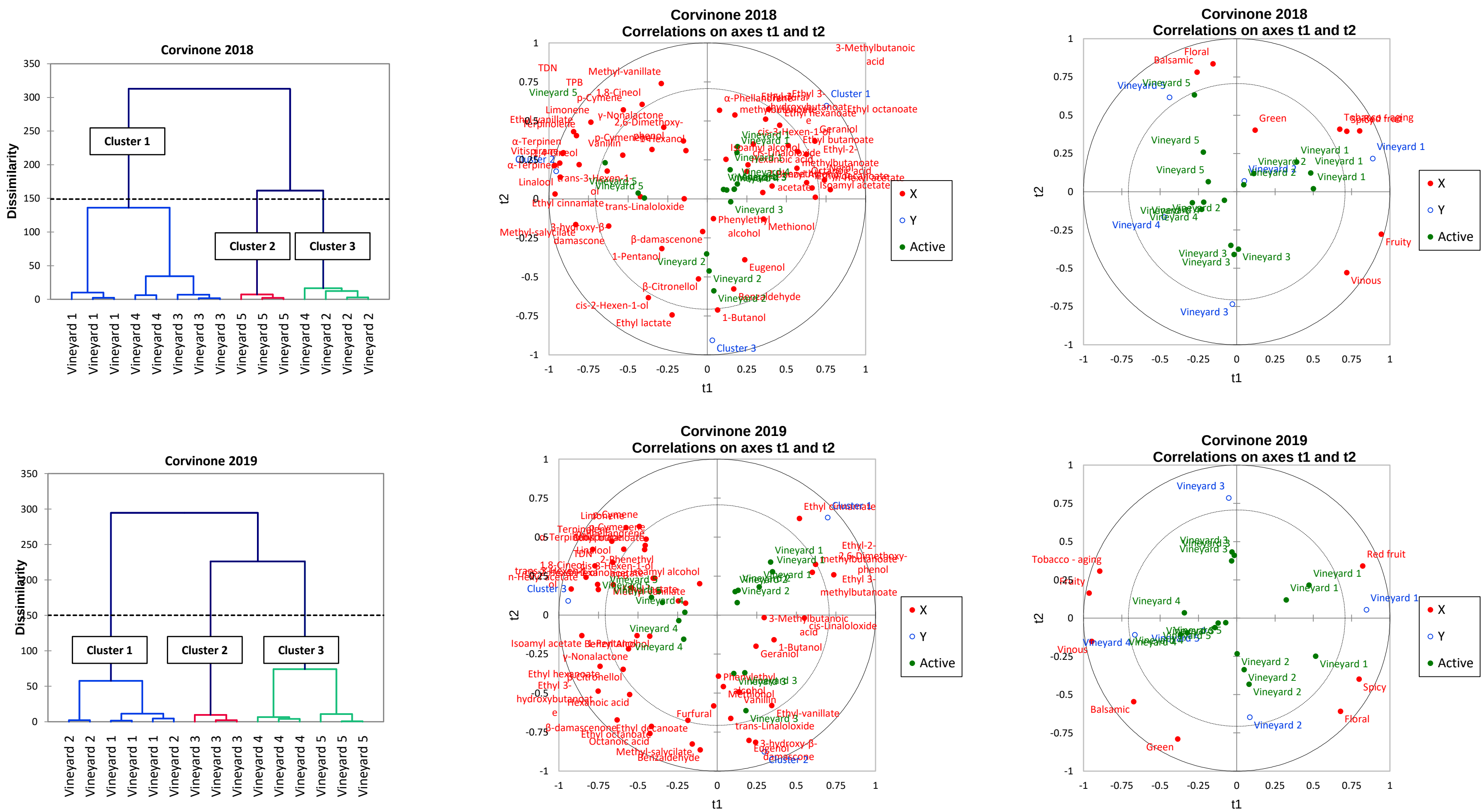


Figure 1.3.1.14. Fresh Corvinone 2018 a) HCA of sorting task data b) PLS-DA analysis of volatile chemical data referred to sensory clusters c) PLS-DA of aroma series and fresh Corvinone 2019 d) HCA of sorting task data e) PLS-DA analysis of volatile chemical data referred to sensory clusters f) PLS-DA of aroma series

In both varieties, sensory clustering displayed a pattern in which V4 and V5 were in most cases grouped together, and V1-V3 were speeded across the other two clusters, the only exception being Corvinone 2018. This clustering did not reflect the chemical diversity observed in individual vintages (**Figures 1.3.1.4** and **1.3.1.5**) or the vintage-independent aroma chemical signatures (**Figures 1.3.1.6** and **1.3.1.7**), but indicate a degree of similarity associated to geographical origin at the level the sub-regions Valpolicella Orientale (V1-V3) and Valpolicella Classica (V4-V5), rather than at the level of individual vineyards. This discrepancy in probably due to the fact that, of all the compounds that are contributing to segmentations based on chemical data, only certain are actually contributing to perceived aroma, and probably also through complex synergistic and suppressive effects. On the other hand, there could be other volatile compounds not determined in this study that could account for sensory segmentation. Moreover, also the composition of the non-volatile matrix could have played a role in determining sensory differences (Robinson, *et al*., 2009). As the actual concentrations of these compounds change significantly with vintage, different odor nuances are perceived and categorized during the sorting task. Nevertheless, the results of the sorting task seem to indicate that this odor categorization, although not sufficiently unique to discriminate individual wines, might eventually reflect certain patterns that could be characteristic of larger geographical origins such as the two distinct sub-regions within Valpolicella. Unfortunately, in terms of number of samples for each sub-region, our dataset was too small to provide conclusive results, but further investigations should be carried out on this important aspect.

To gain insights into the aroma chemical bases of each clusters, the sorting tasks results of each vintage were compared with wines volatile composition by means of PLS-DA, using either raw concentration data or aromatic series (**Figures 1.3.1.13-1.3.1.14**). V4 and V5 Corvina wines were mostly characterized by linear and cyclic terpenes contributing to floral and balsamic series respectively V1-V3 were mostly associated with compounds in the tobacco (norisoprenoids), red fruit (branched-chain esters) and spicy (benzenoids) series. As for Corvinone, V1-V3 wines were mostly associated with red fruit (branched-chain ethyl esters) and spicy (benzenoids) series, whereas for V4 and V5 compounds in the green (C_6 and isoamyl alcohols) and balsamic (cyclic terpenes) series were more characteristic.

1.3.2. Wines obtained from withered grapes

Post-harvest withering is a unique feature of Valpolicella winemaking heritage (Paronetto, *et al*., 2011). While this technique is part of the traditional pool of practices of many winemaking regions worldwide, it is mostly associated with production of sweet or semi-sweet white wines, such as Sicilian Passito and Spanish Jerez. Conversely, in the case of Valpolicella, it is used to produce a dry red wine such as Amarone, as well as a sweet red named Recioto.

The practice of post-harvest withering has an ancient history in the region surrounding Verona. The first written record of its use dates back to the sixth century AD, and refer to the production of a sweet red wine (Paronetto, *et al*., 2011). This tradition remained until the mid-20th century, so that the sweet red wine named Recioto was the most sought after product of the area. Occasionally, fermentation progressed until dryness, especially in seasons with mild temperatures, resulting in a dry wine, to the disappointment of Recioto producers. As, in comparison to Recioto, this dry red was rather bitter, locals started calling it Amarone (*amaro* means bitter in Italian). Nowadays, with the changes in consumers preferences and habits, Amarone has become the flagship wine for Valpolicella, whereas Recioto is limited to small productions from a few committed wineries (Paronetto, *et al*., 2011).

Post-harvest withering is essentially a dehydration process, which takes place in a naturally ventilated room, possibly equipped with a partial control of temperature and relative humidity (Bellincontro, *et al*., 2016). In Valpolicella these rooms are called '*fruttai'*, and can rely on natural as well as forced ventilation, whereas heating is not allowed. Withering normally lasts 100-120 days, with target weight loss typically around 30%. The current regulation imposes that grape to wine yield should not be greater than 40% (Gazzetta ufficia1e 190, 14.08.2019). Although concentration of many grape components occurs obviously during withering, several studies have shown that this is a much more complex process, in which numerous biochemical changes occur inside the grape berry. In particular, it has been shown that changes to the levels of expression of several genes result in large modifications in the pool of phenolic and volatile compounds (Zenoni, *et al*., 2016) (Bellincontro, *et al*., 2016) (Slaghenaufi, *et al*., 2020). As a consequence, concentration is not the only expected outcome of withering, and in fact for several grape compounds a net decrease might even be observed.

In the present study, we have investigated the characteristics of wines obtained from post-harvest withered grapes from the same five vineyards previously described, for both Corvina and Corvinone. As in the previous section, our aim was to characterize the aroma chemical signatures of the different single vineyard wines, so that we could evaluate the existence of chemical markers associated with geographical identity. Sensory evaluation (sorting task) of the wines also allowed to establish relationships between these markers and patterns of perceived odor similarities. Withering was carried out in the facilities of the commercial winery that provided the grapes, so that it reflected real-life production standards. Winemaking was carried out following a standard red winemaking protocol. The yeast used to inoculate the fermentations was the one most commonly used by wineries for Amarone production, characterized by high osmotic stress and ethanol tolerance.

1.3.2.1. Overview of grape technological characteristics in the three vintages

Grapes at the end of the withering treatment, showed different sugar content also due to the different starting levels. Possible influences of both ripeness and sugar content on wine volatile composition were assessed a posteriori. With regard to the nitrogen content, it was also chosen not to add any external source (**Appendix 1.3.2.1**). Ranges between the different vineyards of glucose + fructose and nitrogen contents were rather wide, up to 112 g/L of sugar and 196 mg/L of YAN. Main enological parameters of fresh grapes wines at the end of alcoholic fermentation are shown in **Appendix 1.3.2.2.**

1.3.2.2. Overview of different vintages volatile chemical profiles

Two-way ANOVA was performed on the volatile chemical data set to assess the impact of different source of variability such as vintages and vineyards, as well as their interaction (**Appendix 1.3.2.3**). As previously done for fresh grape the two varieties have been treated separately and their impact on the aromatic profile have been assessed in the next sub-chapter. Also in this case the impact of grape origin was lower than that of vintages since roughly 40% of the compounds were impacted. Conversely vintages had a significant impact on 87% of the volatile compounds of Corvina and 77% of Corvinone respectively. However, again, Vineyards*Vintages interaction had a major impact on volatile chemical profiles, since in both varieties 95% of volatile compounds were significantly affected. Once more, this last indication represented a good starting point for this study, as differences due to grape origin although expressed in combination with vintage are a source of diversity for wines.

As for fresh grapes, multivariate analysis of the whole data set showed a major effect of vintage compared to variety or vineyard (**Figure 1.3.2.1**). The plot was obtained using all components, and 42.83% of the total variance was explained with the first principal components with PC1 accounting for 28.55% of the variance and PC2 accounting for 14.28%. In addition to the vintage, an appreciable effect of the variety was evident. Since grapes were the same employed in the previous part of this study, in addition to withering treatment, meteorological variables, for example temperature and rainfall, could have played a role as did in fresh grapes wines.

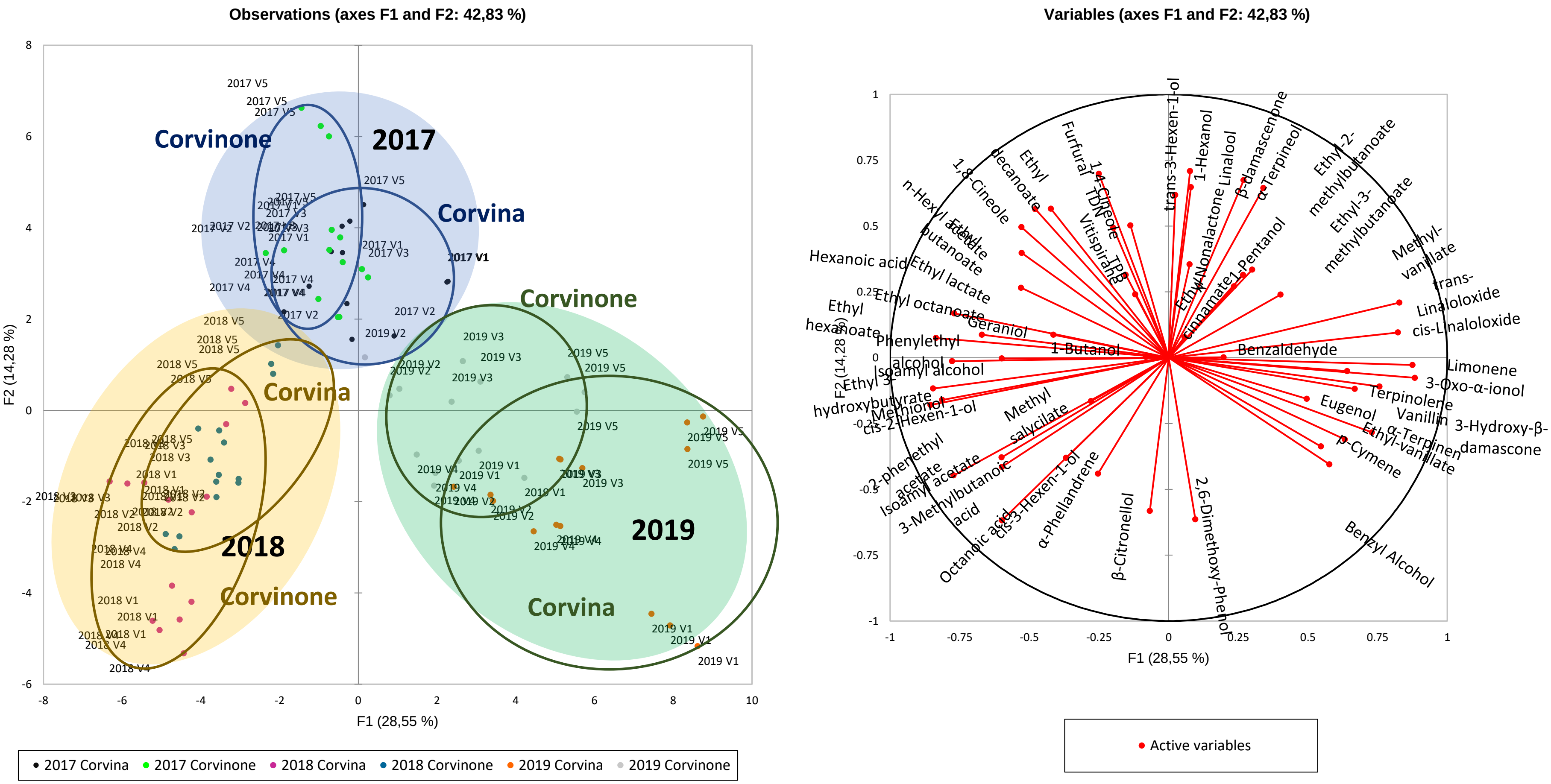


Figure 1.3.2.1. PCA analysis of all withered grape wines with significant different compounds. Circles in observations plot are not the result of statistical processing but are useful for a better understanding of the plot

1.3.2.3. Varietal volatile patterns in Corvina and Corvinone

As for fresh grape wines, Corvina and Corvinone were treated separately and differences between varieties were firstly evaluated. Wines showed consistent differences of the chemical volatile profiles of Corvina and Corvinone (**Appendix 1.3.2.4**). Among the volatile compounds analysed, twenty-two compounds exhibited statistically significant differences for the 2017 vintage, twenty-three for the 2018 and, twenty-five for the 2019 (**Appendix 1.3.2.5**). PCA analyses indicated that 41.77% of the total variance was explained with the first two principal components, with PC1 and PC2 accounting for 27.47% and 14.30% respectively (**Figure 1.3.2.2)**. Corvina and Corvinone wines were clearly differentiated on PC1, where all the Corvina wines, a part 2017 V4, showed positive values and all Corvinone wines showed negative values.

Terpenes were strong differentiation drivers. Their content was generally higher in Corvina, ranging from 33.03 µg/L to 72.46 µg/L, although overall levels were lower than in fresh grape wines. Linalool in Corvina was often beyond its OT, while in Corvinone it never was, suggesting that it could be a key compound for the metabolic (and sensory) discrimination of the two varieties, also in wines produced with withered grapes. As this study investigated wines produced replicating certain variables typical of commercial productions, it was not possible to make a direct comparison between wines produced with fresh grapes and those produced with withered grapes, because different yeasts were employed. However, withered wines showed slightly lower content of terpenes compared to fresh grapes wines. Assuming only an effect due to the concentration caused by dehydration, the content should have been higher and not lower. Bellincontro *et al.*, (2016) also observed a decrease in wines terpenes pool as a result of the oxidative process which occurs during the postharvest withering.

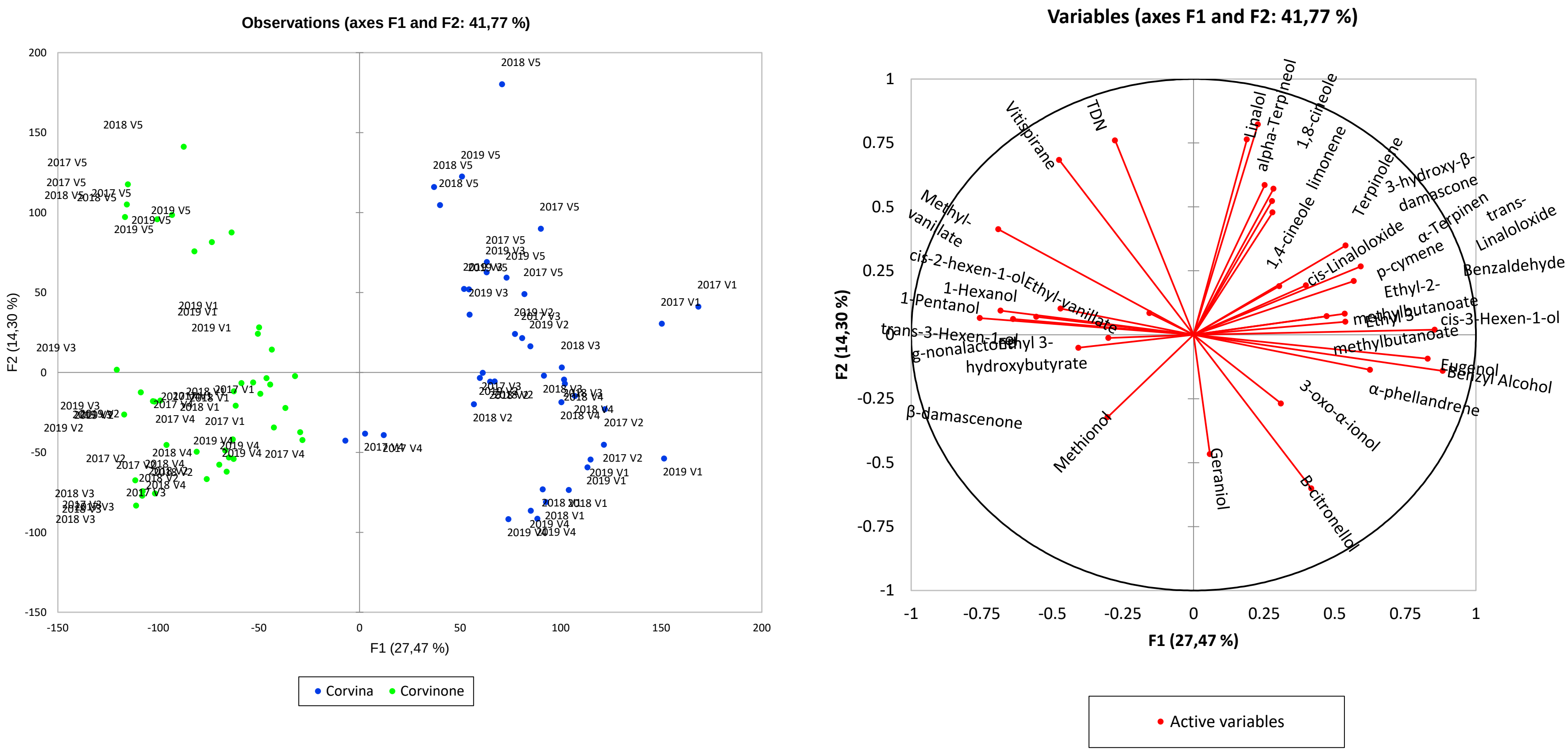


Figure 1.3.2.2. PCA analysis of all studied withered grapes wines performed with significant different compounds between varieties

Corvinone wines showed an average higher content of norisoprenoids in all three vintages, ranging from 7.12 μg/L to 98.12 μg/L, in particular of β-damascenone and vitispirane. TDN attained concentrations that were rather high for red wines, suggesting a possible sensory contribution of this compound to Amarone aroma profile. Norisoprenoids contents, unlike that of terpenes, showed an increase compared to fresh grapes, up to 75.57 μg/L.

Increased levels of C_6 alcohols were found in wines from withered grapes compared to wines from fresh grapes, in agreement with the literature (Genovese, *et al.*, 2007). Also in this case, like in fresh grapes wines, despite being compounds usually associated with technological steps, in particular grape crushing, C_6 alcohols played a role in varietal differentiation. While the total content was higher in Corvinone wines, cis-3-hexen-1-ol was a marker of Corvina wines, where it attained levels close to the reported odor threshold of 400 μg/L.

Benzenoids were also a clear element of varietal distinction. Corvina was found to be richer in total benzenoids, including eugenol, while Corvinone were found to be richer in vanillic esters.

Among the fermentative compounds, the branched-chain fatty acid ethyl esters were more present in Corvina wines, showing an average content between 1.2- and 1.3-fold higher than Corvinone. Considering acetate esters, isoamyl acetate in the first two vintages was generally more abundant in Corvina wines, while in the third vintage in Corvinone. Ethyl esters in 2018 were more present in Corvina, while in 2019 in Corvinone. Vintage 2017 did not show a specific trend.

To gain an insight in the possible sensory implications of varietal sensory characteristics of Corvina and Corvinone passito wines, aromatic series were developed as for fresh grapes wines (**Figure 1.3.2.3**) (individual OAVs in **Appendix 1.3.2.6**). Corvina wines showed 1.3-fold higher red fruity parameter during all the three vintages. Furthermore, Corvina wines showed higher spicy, floral, balsamic parameter. These differences, however, are not clear-cut, due to the wide chemical variability due to grape origin and vintages. For example, the 2018 vintage showed similar spicy and balsamic parameters in both varieties. Corvinone showed higher fruity parameter in vintage 2017 and 2019 and similar levels in vintage 2018. As for the tobacco-evolutive parameter, Corvinone showed twice the levels of Corvina.

Corvina and Corvinone, also after withering, were grapes capable of producing wine different both from a metabolic and also from an aromatic point of view. The difficulties encountered in the case of withered grapes in finding clear patterns attributable to the variety, especially from an aromatic point of view, was due, again, to the vintage effect but also to the influence of the grape origin. In particular, this last aspect is of particular interest if we consider grape origin as a variable capable of modifying the aromatic profile of wine even when produced with grapes that have undergone withering treatment.

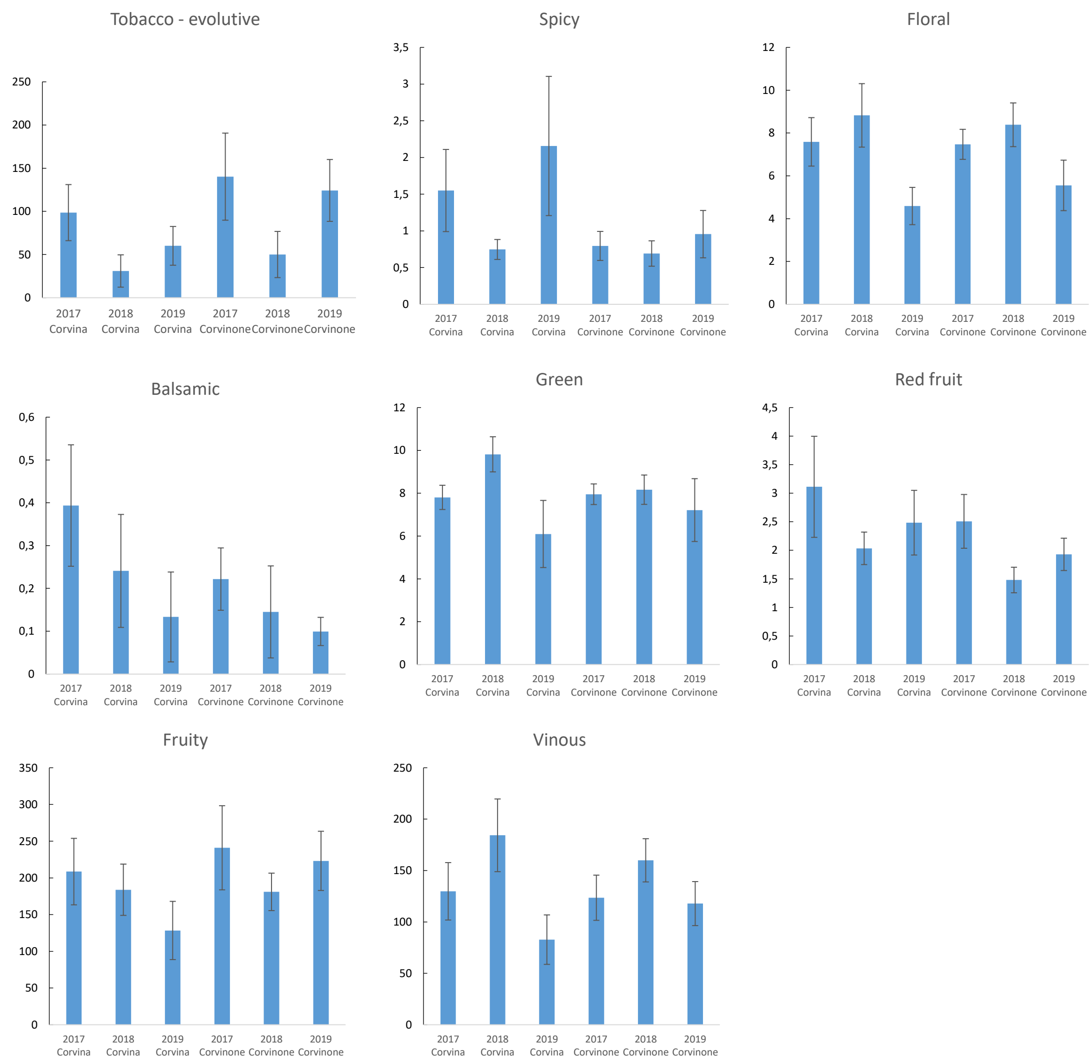


Figure 1.3.2.3. Aromatic series (sum of individual OAVs) of different withered grape cultivar-vintages combinations

1.3.2.4. Influence of geographical origin on volatile chemical signatures of single vineyards withered grape wines

Aroma chemical signatures attributable to vineyards were searched, initially by applying multivariate analyses to the data obtained from each vintage. Results (**Figures 1.3.2.4** and **1.3.2.5**) showed clearly the existence of different volatile profiles, but variations due to vintage made it difficult to highlight any aroma chemical signature specific of the different vineyards (volatile chemical composition in **Appendix 1.3.2.7 -1.3.2.11**). Overall, the data supported the view that, also for wines from withered grapes, grape origin introduced significant variation in wine volatile composition, affecting a diversified range of metabolites. In itself, withering is therefore not causing a deterioration in the possibility that single vineyard wines express a diversity of volatile patterns. The observed diversity was particularly remarkable in the case of V1-V3, which are small parcels close to each other within the same estate (**Figure 1.2.1** and **Table 1.2.1**). While in Corvinone 2018 they were relatively close for both varieties, in the other two vintages the volatile chemical signatures of these wine did not show specific patterns in the multivariate analysis. This scenario highlights the complexity of unravelling chemical markers representative of the uniqueness of each vineyard (ad therefore of intrinsically more complex variables as typicality, regionality or terroir), beyond the major influence of vintage.

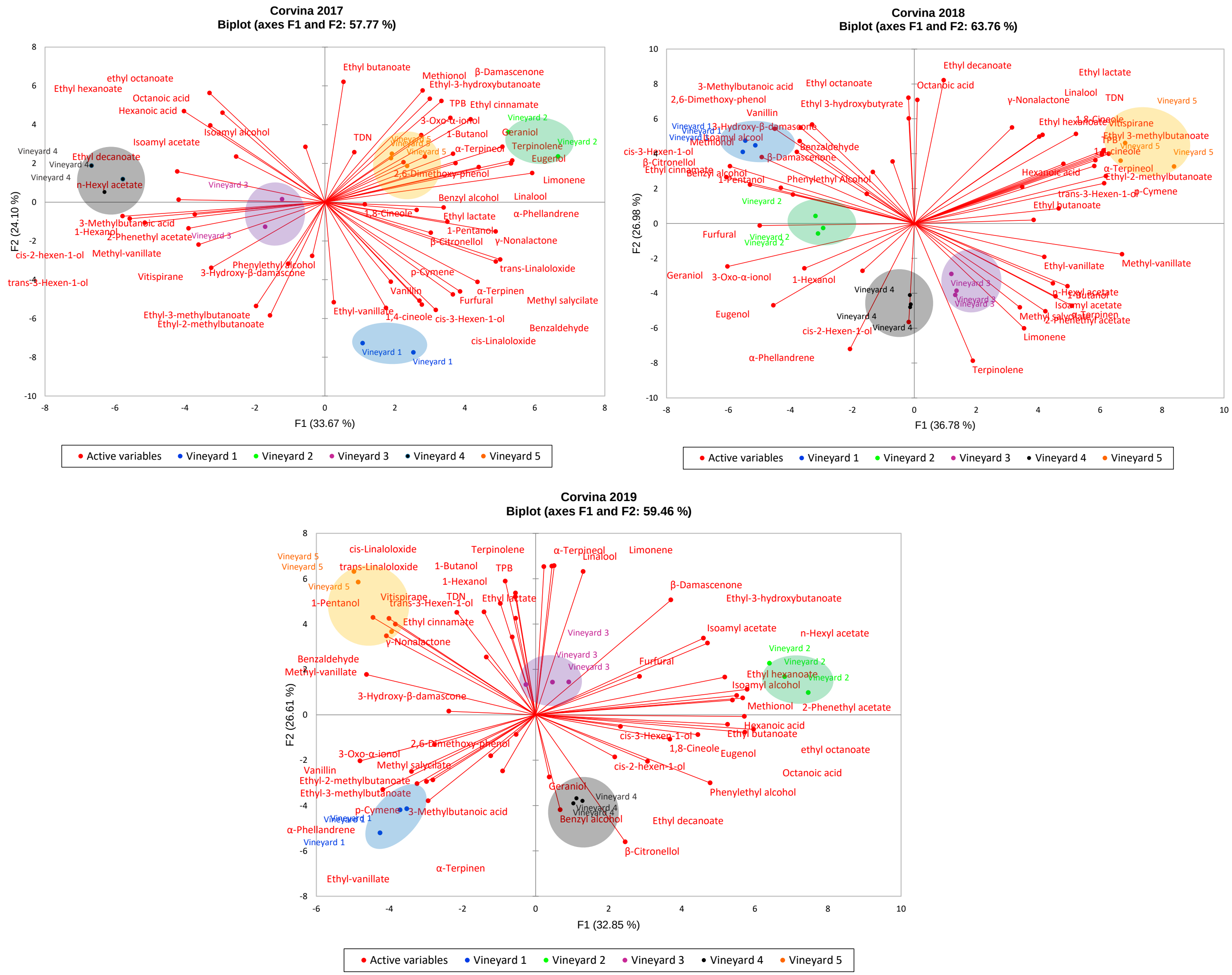


Figure 1.3.2.4. PCA analysis of a) 2017 b) 2018 and c) 2019 withered Corvina wines. Circles are not the result of statistical processing but are useful for a better understanding of the plot

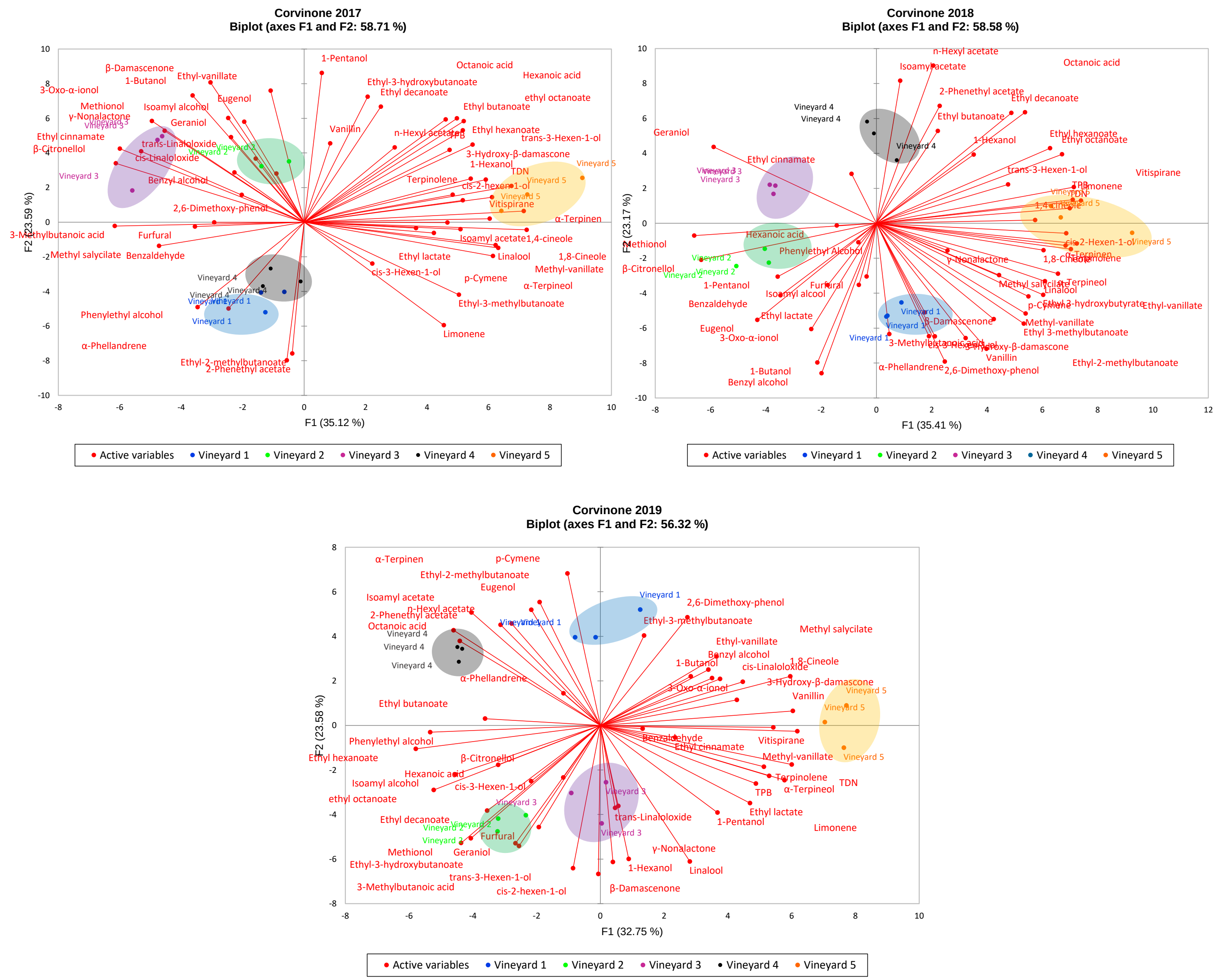


Figure 1.3.2.5. PCA analysis of a) 2017 b) 2018 and c) 2019 withered Corvinone wines. Circles are not the result of statistical processing but are useful for a better understanding of the plot

Nevertheless, some recurrent features were evident. In Corvina wines V5 was associated with linalool, α-terpineol and other terpenes, TPB and TDN, V4 with phenylethyl alcohol, acetate esters and methyl vanillate, V2 with β-damascenone and ethyl 3-hydroxybutanoate. In Corvinone wines V5 was again associated with most monoterpenes as well as vitispirane TPB and TDN, V1 and 4 with phenylethyl alcohol, its acetate, and ethyl 2-methylbutanoate, and V2 and 3 with geraniol and β-citronellol. To overcome the vintage effect and in consideration of the complexity of the different patterns observed, data of each vintage before being submitted to PCA have been rescaled from 0 to 100, and then aggregated into a single matrix as previously done for fresh grapes wines. PCAs were performed with significant different compounds between vineyards (**Appendix 1.3.2.13** and **1.3.2.14**).

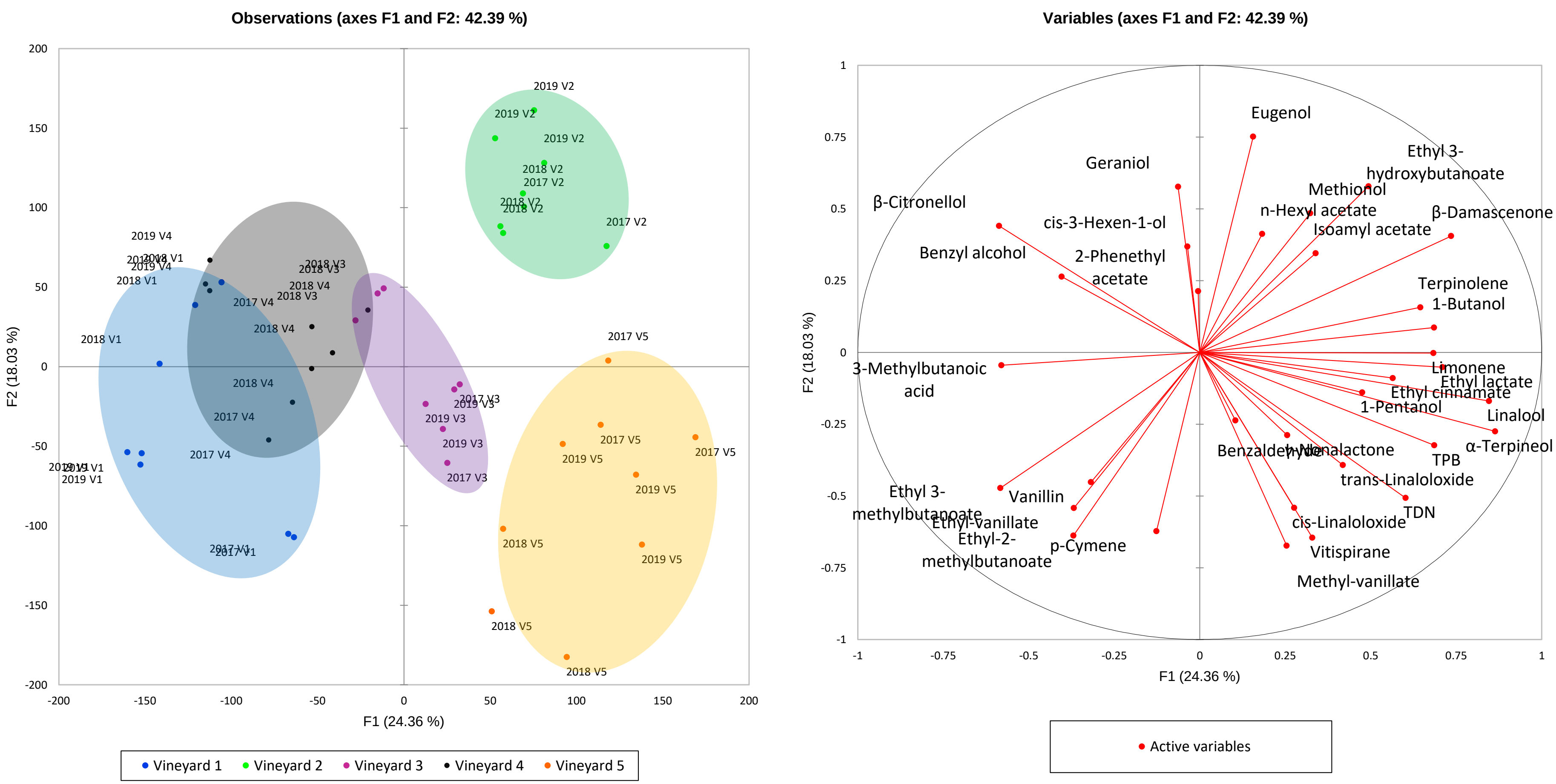


Figure 1.3.2.6. PCA analysis of withered Corvina wines with significant different volatile compounds vintage rescaled (from 0 to 100). 2017-2019 refers to vintages V1-V5 refers to vineyard 1-vineyard 5. Circles are not the result of statistical processing but are useful for a better understanding of the plot

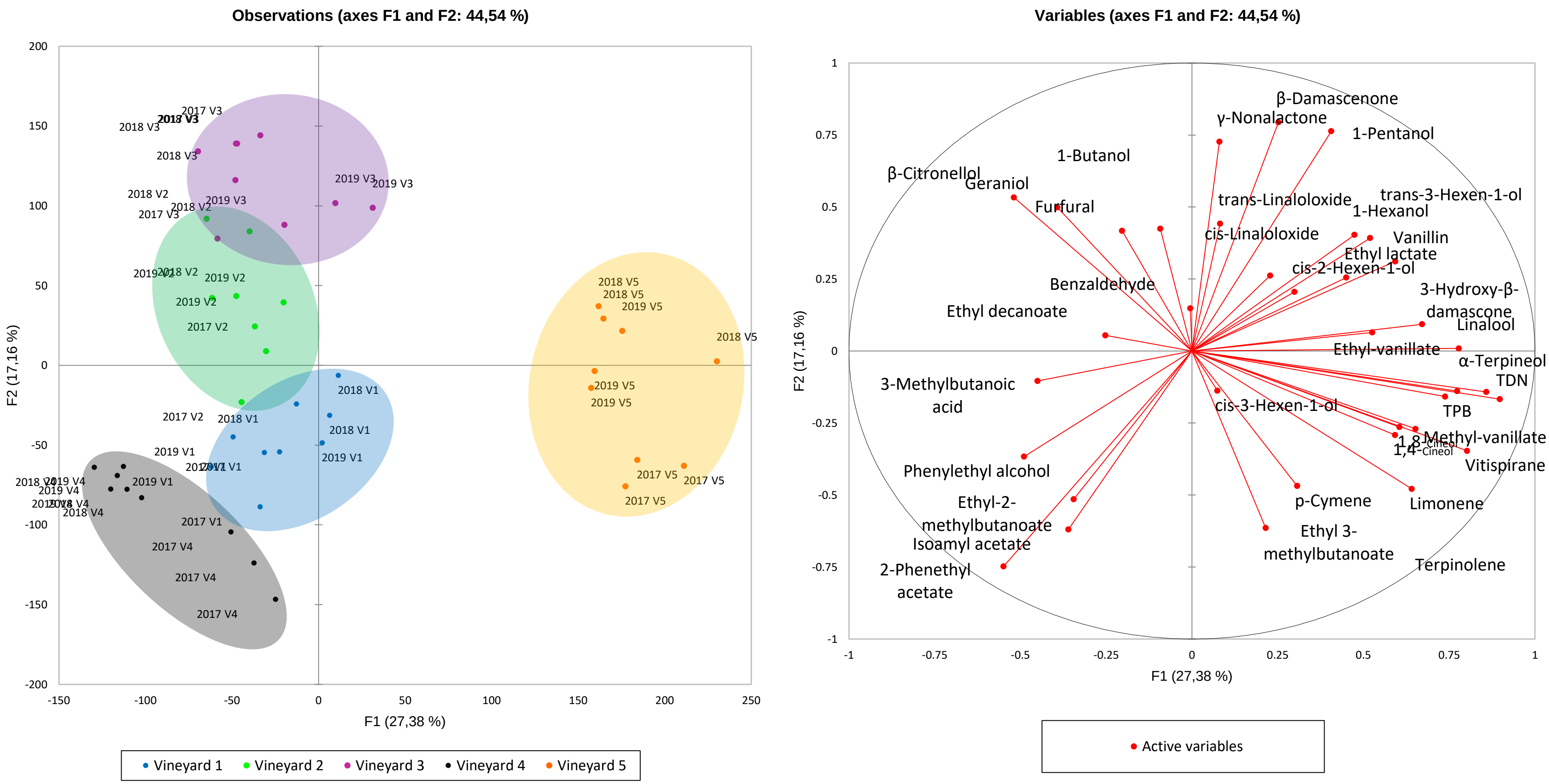


Figure 1.3.2.7. PCA analysis of withered Corvinone wines with significant different volatile compounds vintage rescaled (from 0 to 100). 2017-2019 refers to vintages V1-V5 refers to vineyard 1-vineyard 5. Circles are not the result of statistical processing but are useful for a better understanding of the plot

This approach proved to be effective in identifying the aroma chemical signatures in both Corvina and Corvinone wines (**Figures 1.3.2.6** and **1.3.2.7**). In fact, the single vineyard wines were clustered together regardless (despite) of vintages. In the case of Corvina, the clustering shows different analogies with that of fresh Corvina, with chemical signatures of V2 and V5 wines positioned on the same side of PC1, associated with increased content of linalool, α-terpineol, TPB, TDN, damascenone, eugenol, isoamyl acetate, and V1, V3 and V4 wines positioned on the left side of PC1, associated with branched-chain fatty acids ethyl esters, geraniol, citronellol, vanillin. In the case of Corvinone, while in the fresh grape wines V1-3 wines formed a single cluster, in this case they were separate. In addition, V5 wines showed the greatest differences with the rest of the samples.

As previously done for fresh grapes a Hierarchical Cluster Analysis was performed using the same compounds of the multivariate analysis (**Figure 1.3.2.8**). In Corvina four clusters were formed, the first comprising V2, the second V5, the third V1 and the fourth V3 and V4, with 2019 V4 which spanned from the fourth to the third cluster. Interestingly within Cluster 4 sub-clusters associated with individual vineyards were observed. In Corvinone, three clusters were formed, a first cluster formed by V5, a second by V2 and V3 and a last one by V1 and V4 with 2017 V2 spanned from cluster 2 to the cluster 3.

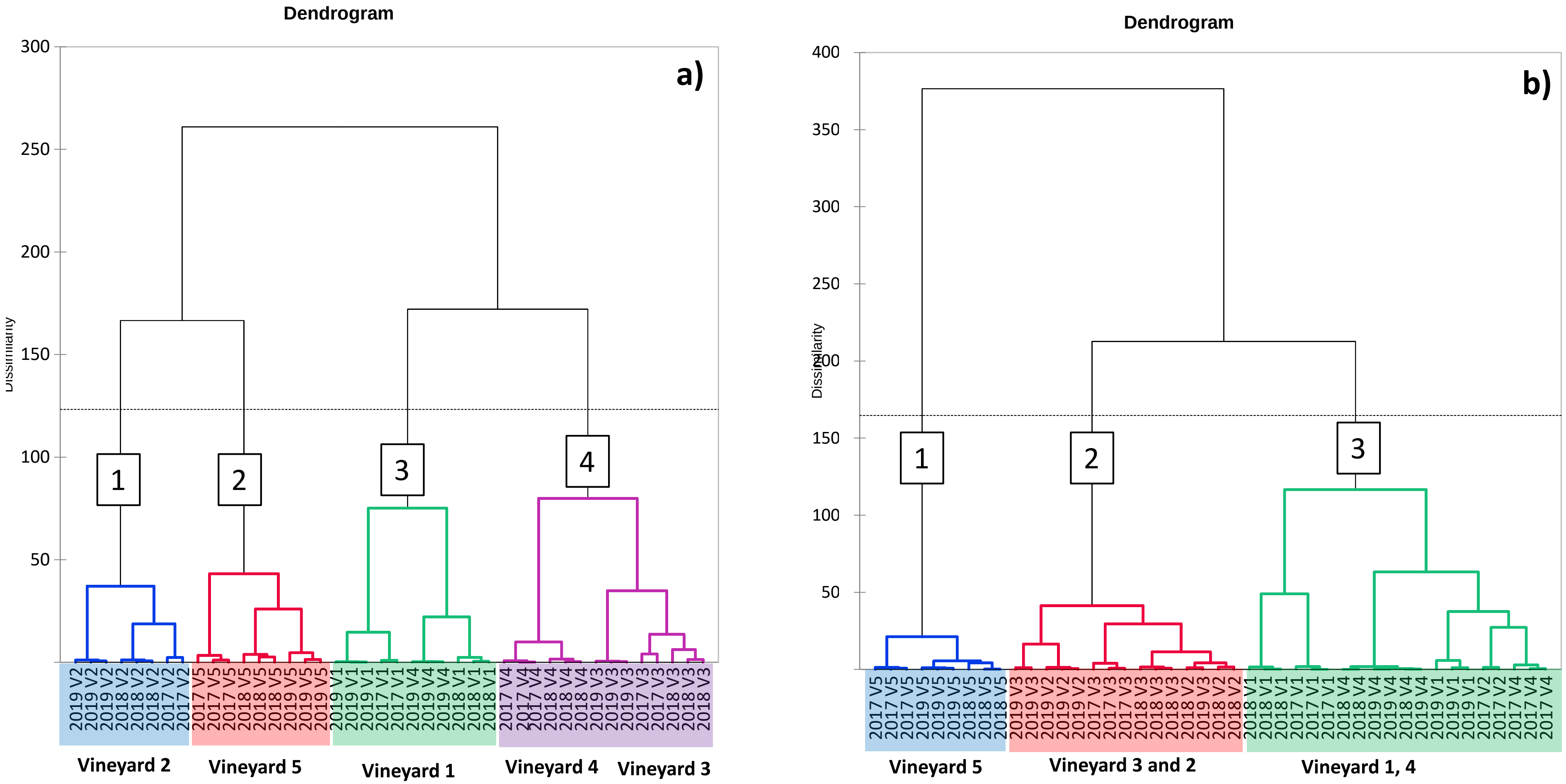


Figure 1.3.2.8. HCA analysis of chemical data of withered a) Corvina and b) Corvinone wines

Terpenes and norisoprenoids were the main drivers of vineyards aroma chemical signatures, but many other compounds such as vanillates, branched chain ethyl esters and acetate ester contributed significantly. The content of total terpenes and norisoprenoids, as well as that of some individual metabolites, is shown in **Figures 1.3.2.8-1.3.2.10**

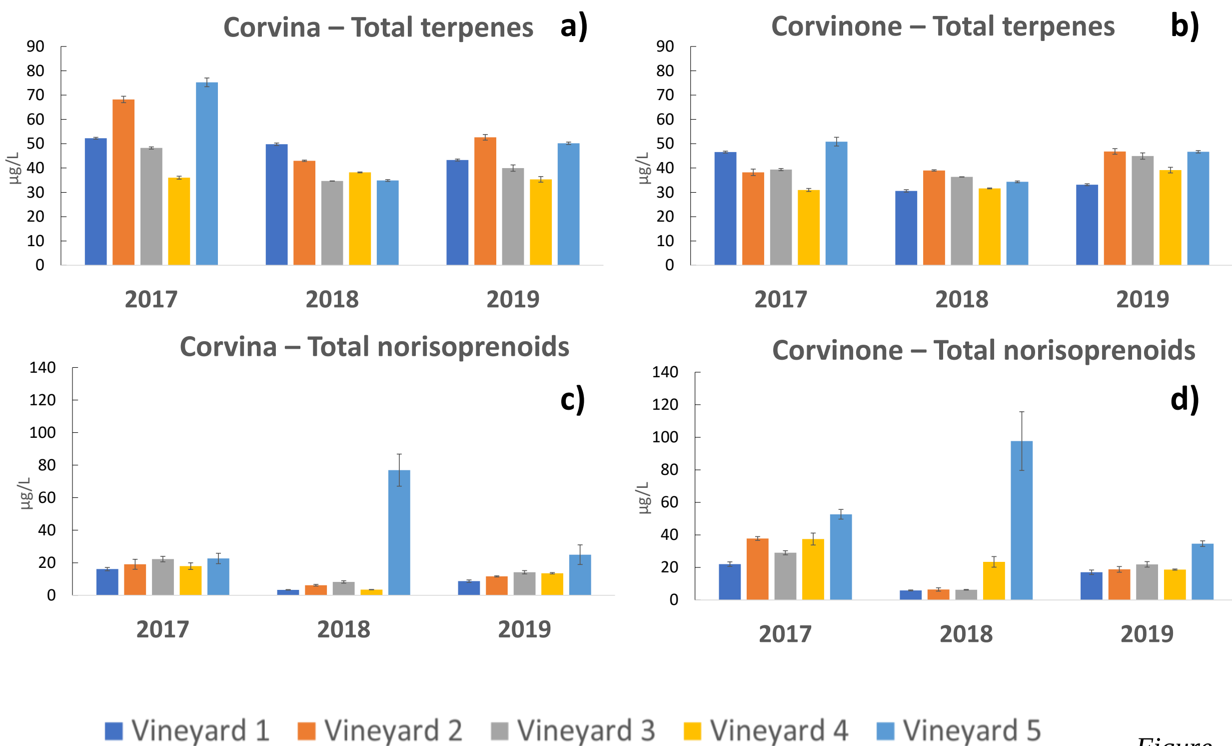


Figure 1.3.2.9. Content of withered a) Corvina total terpenes b) Corvinone total terpenes c) Corvina total norisoprenoids d) Corvinone total norisoprenoids.

Certainly, one of the drivers of differentiation were terpenes showing variations between vineyards up to twice the content (**Figure 1.3.2.9**). Linalool was the main terpene also in wines from withered grapes, and despite concentration effects of withering, its content was lower than in wines made from fresh grapes. As already seen for fresh grape wines, Corvina showed much higher content than Corvinone. In turn, Corvinone as in fresh grape wines, showed a higher norisoprenoid content apart from damascenone. Whether this was the result of concentration or specific metabolic factors it is not clear. Zenoni *et al*., (2016) reported different behaviors of various norisoprenoids during withering, some increasing, others not.

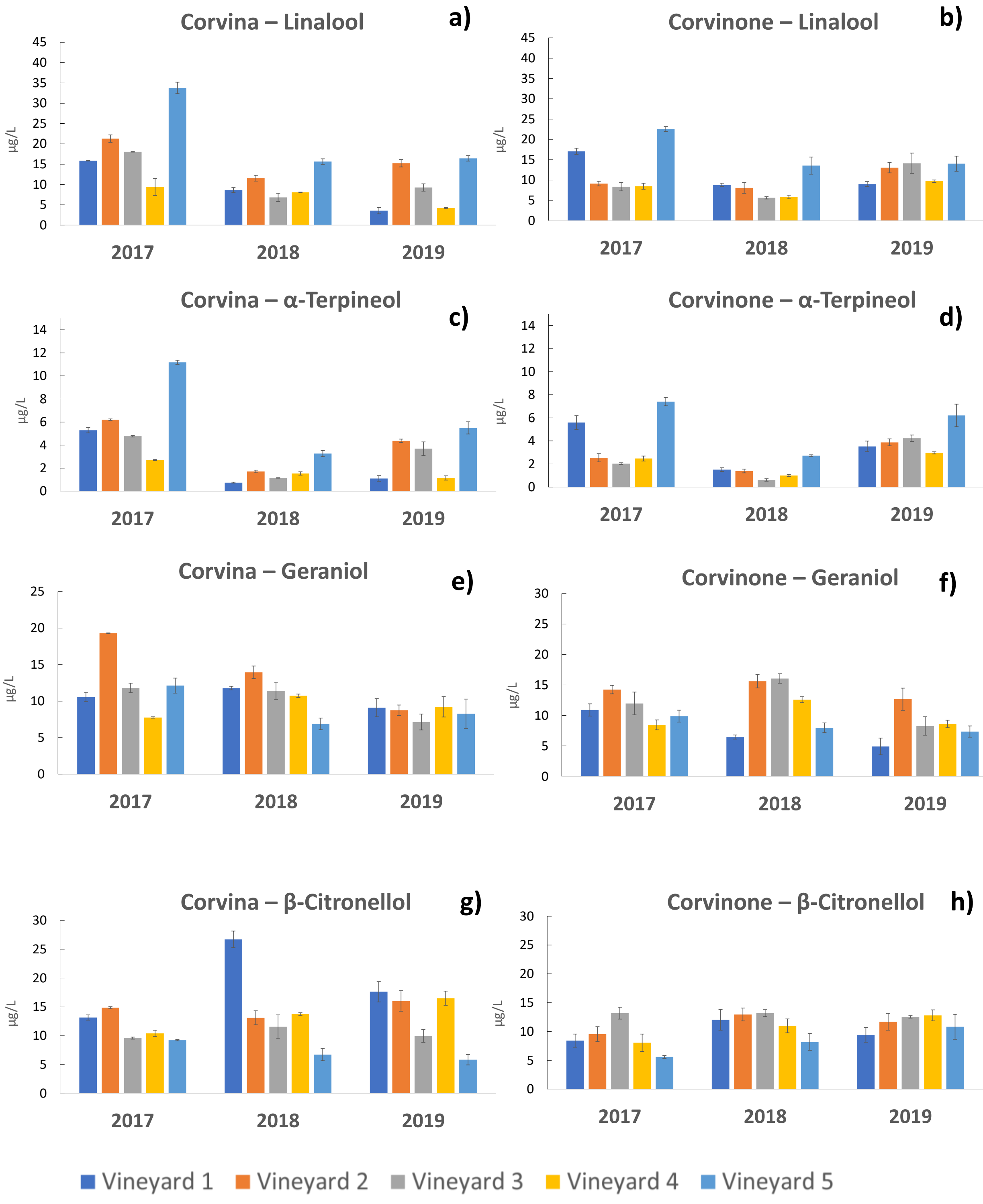


Figure 1.3.2.10. Content of withered a) Corvina linalool b) Corvinone linalool c) Corvina α-terpineol d) Corvinone α-terpineol e) Corvina geraniol f) Corvinone geraniol g) Corvina β-citronellol h) Corvinone β-citronellol.

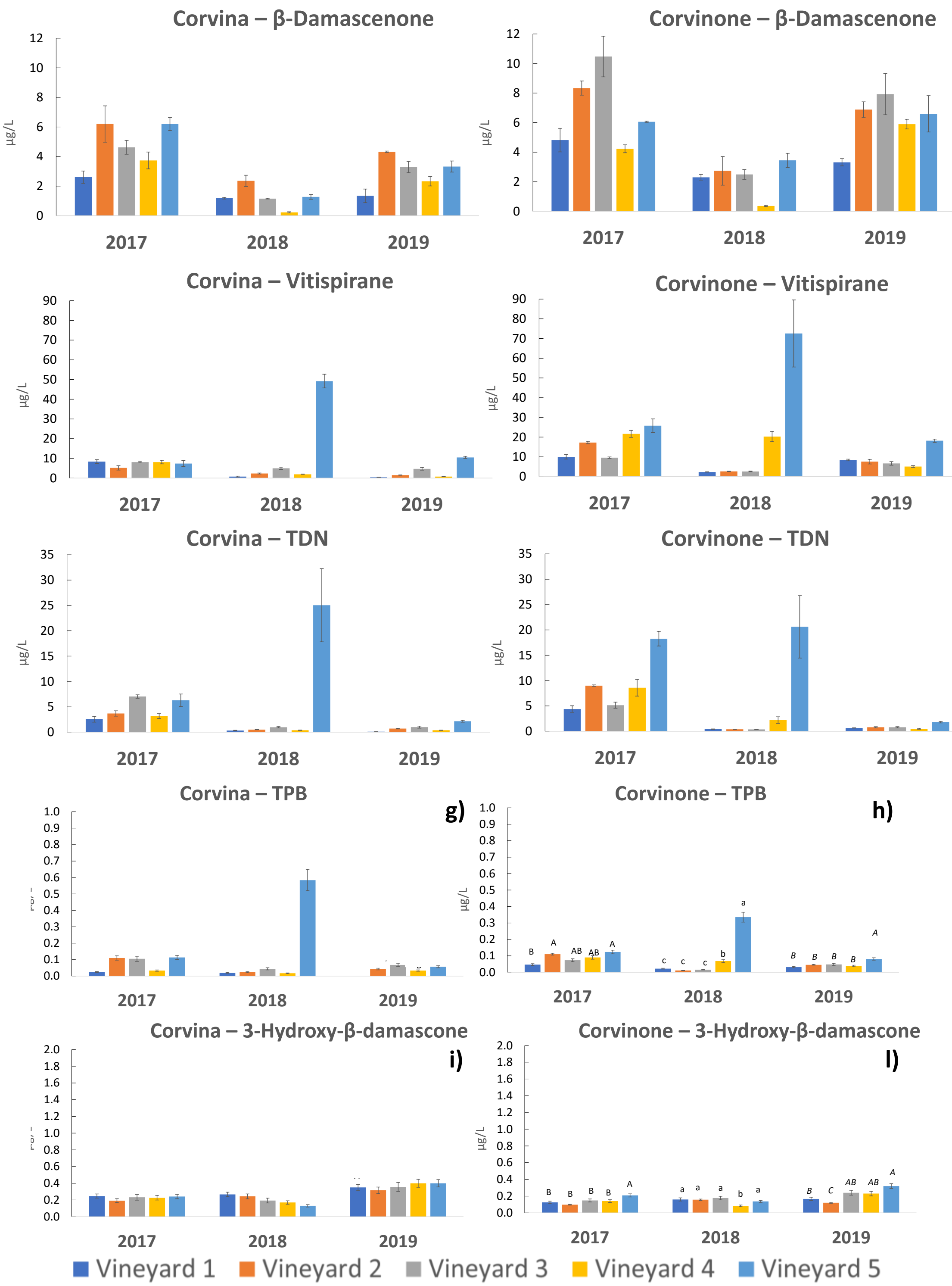


Figure 1.3.2.11. Content of withered a) Corvina β-damascenone b) Corvinone β-damascenone c) Corvina Vitispirane d) Corvinone Vitispirane e) Corvina TDN f) Corvinone TDN g) Corvina TPB h) Corvinone TPB i) Corvina 3-hydroxy- β-damascone l) Corvinone 3-hydroxy- β-damascone. .

The influence of grapes origin on terpenes and norisoprenoids volatile profile was observed on passito wines as well as in fresh grape wines, (Wen, *et al*., 2005) (Sabon, *et al*., 2002) (Robinson, *et al*., 2014) (Slaghenaufi, *et al*., 2019). Interestingly, despite grape dehydration and use of a different yeast strain, many key components of the signatures found in fresh grape wines were found also in withered grape wines. This last consideration was not obvious, as the literature on postharvest withering indicate that, beyond the simple concentration of aroma compounds and precursors, withering can also alter their patterns. (Zenoni, *et al*., 2016) (Slaghenaufi, *et al*., 2020). Terpenes, although decreased in concentration retained their role as drivers of the aroma signature of the single vineyard wines, with patterns similar to fresh grapes wines. Conversely, for norisoprenoids, withering resulted in significant increases in their concentrations enhancing the characteristic features of the aroma signature of V5 wines, which became markedly characterized by the high content of the various non-megastigmane form norisoprenoids TDN, TPB, vitispirane.

As in fresh grape wines, the contribution of certain fermentative compounds to chemical signatures of geographical origin was also important here. Branched chain fatty acid ethyl esters contributed to aroma signatures-related patterns, although, especially in Corvinone, without major quantitative differences (**Figure 1.3.2.12**). Isoamyl acetate, the main acetic esters, was both a powerful driver of vineyard differentiation, especially in Corvinone, with variation between vineyards up to twice the content, but at the same time contributed, especially in Corvinone, to recurring patterns of single vineyard wines aroma chemical signature. (**Figure 1.3.2.13**). Conversely, ethyl esters, despite the fact that they, strong drivers of differentiation for individual vintage (**Figures 1.3.2.4** and **1.3.2.5**), did not show recurrent patterns associated with aroma signatures, as shown in **Figures 1.3.2.6** and 1.**3.2.7.**

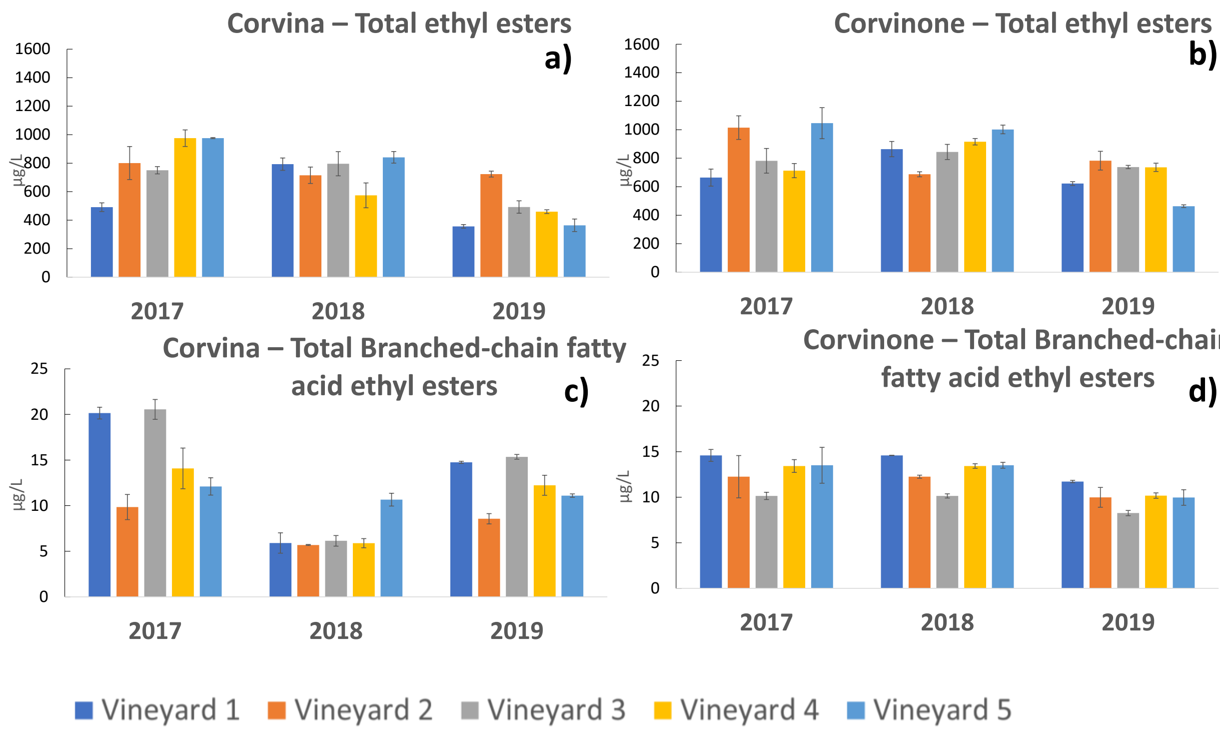


Figure 1.3.2.12. Content of withered a) Corvina total ethyl esters b) Corvinone total ethyl esters c) Corvina total branched chain fatty acid ethyl esters d) Corvinone total branched chain fatty acid ethyl esters. .

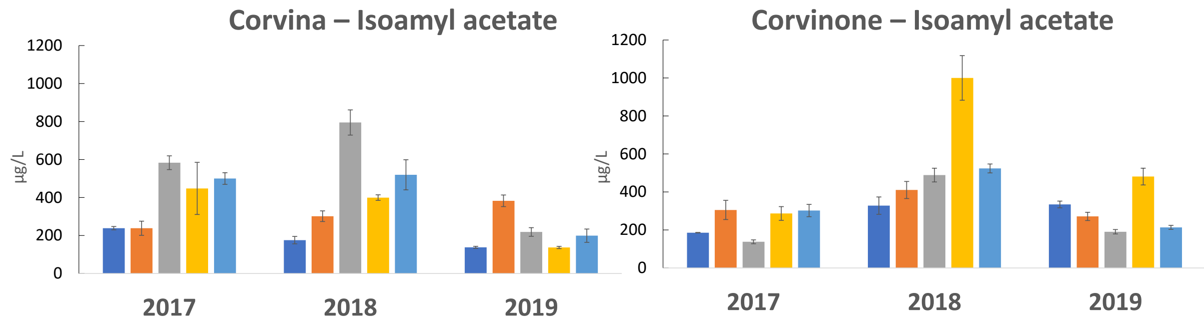


Figure 1.3.2.13. Isoamyl acetate content in withered a) Corvina and b) Corvinone wines.

In **table 1.4.1** correlations between the content of volatile compounds between Corvina and Corvinone of the same vintage are shown. For several compounds good correlations were observed between varieties, indicating that the vineyard-related patterns were very similar between varieties. All norisoprenoids and terpenes, except β-citronellol and α-phellandrene, some benzenoids and C_6 alcohols, showed significant correlations, although not all with a high correlation coefficient.

Among fermentative compounds ethyl and acetate esters as well fatty acids and some alcohols also showed related patterns between varieties.

Table.1.4.1. Correlation coefficients (R^2) between withered Corvina and Corvinone volatile compounds of the same vintage

Compound	R^2	Compound	R^2
1-Butanol	0.178	Hexanoic acid	**0.642**
Isoamyl alcohol	**0.352**	trans-Linaloloxide	**0.395**
1-Pentanol	0.001	cis-Linaloloxide	**0.340**
Phenylethyl alcohol	**0.266**	Linalool	**0.598**
Methionol	**0.624**	α-Terpineol	**0.701**
1-Hexanol	0.082	β-Citronellol	0.010
trans-3-Hexen-1-ol	0.025	Geraniol	**0.261**
cis-3-Hexen-1-ol	0.247	α-Phellandrene	0.087
cis-2-hexen-1-ol	**0.650**	α-Terpinen	**0.242**
Isoamyl acetate	**0.762**	1,4-cineole	0.177
n-Hexyl acetate	**0.468**	Limonene	**0.688**
2-Phenethyl acetate	**0.616**	1,8-Cineole	**0.723**
Ethyl-2-methylbutanoate	0.056	p-Cymene	0.238
Ethyl-3-methylbutanoate	0.007	Terpinolene	**0.719**
Ethyl lactate	**0.515**	β-Damascenone	0.162
Ethyl butanoate	**0.588**	Vitispirane	**0.698**
Ethyl-3-hydroxybutanoate	**0.700**	TPB	**0.629**
Ethyl hexanoate	**0.299**	TDN	**0.549**
ethyl octanoate	**0.570**	3-Oxo-α-ionol	**0.819**
Ethyl decanoate	**0.454**	3-Hydroxy-β-damascone	**0.360**
Ethyl cinnamate	**0.348**	Furfural	**0.744**
3-Methylbutanoic acid	0.175	Benzaldehyde	0.058
Octanoic acid	**0.775**	Benzyl alcohol	**0.305**
		Vanillin	0.113
		Methyl-vanillate	0.006
		Ethyl-vanillate	**0.550**
		Methyl salycilate	0.012
		Eugenol	0.144
		2,6-Dimethoxy-phenol	**0.542**
		γ-Nonalactone	0.001

Bold values show significant correlation (Pearson. α=0.05)

These results indicate that, as in the case of fresh grapes wines, the concentration of many compounds of both varietal and fermentative origins, as well as the way they varied between vineyards, was affected by the vineyards themselves even to a greater extent than variety.

1.3.2.5. Relationship between aroma chemical signatures and wine sensory identity

To assess to which degree aroma chemical signatures could be reflected in wines sensory features, 2018 and 2019 samples of wines from withered grapes were submitted to sorting task analysis. This same approach was also used in the previous section in order to identify recurring clusterization reflecting the geographical origin, the corresponding aroma chemical signatures or a combination of these.

In the case of wines from fresh grape, the sorting task had indicated a recurring pattern of clusterization, with V4 and V5 grouped usually in the same cluster, and V1-V3 arranged in the two other clusters (**Figures 1.3.2.14 - 1.3.2.15).** This appeared of some interest considering the V4 and V5 are located in the Valpolicella Classica sub-region, whereas the others are in Valpolicella Orientale (see **Figure 1.2.1**) Here the situation was less defined (**Figures 1.3.2.13-1.3.2.14)**. In vintage 2018, in both Corvina and Corvinone, HCA clustering displayed a pattern associated with sub-region of grape origin (Valpolicella Orientale – V1-V3 and Valpolicella Classica – V4-V5), although only in Corvinone V1-V4 were in one single cluster Conversely. in 2019 vintage, V2 and V3 were always in the same cluster but V1 appeared more closely related toV4 and V5. In all cases HCA biological replicates were projected close to each other in the dendrogram. Overall it can be concluded that, in the case of withered grapes, patterns of odor similarities across the sample set could still be observed. As in the case of fresh grape wines, these patterns did not reflect the segmentation samples based on chemical compounds. However, in the case of withered grape wines, patterns of odor similarities were also less systematic and only marginally associated with geographical origin of the grape.

The chemical bases of sorting tasks clusters were investigated by means of PLS-DA using raw volatile chemical data as well as aroma series (**Figures 1.3.2.13-1.3.2.14).** Sorting task clusters were associated with individual volatiles as well as with odor series but association between aromatic parameters and vineyard of grape origin was not systematic. In 2018 V1-V3 were mostly associated with compounds in the fruity (branched chain ester, damascenone and some ethyl esters), vinous (all fermentative compounds) and floral (terpene) series.

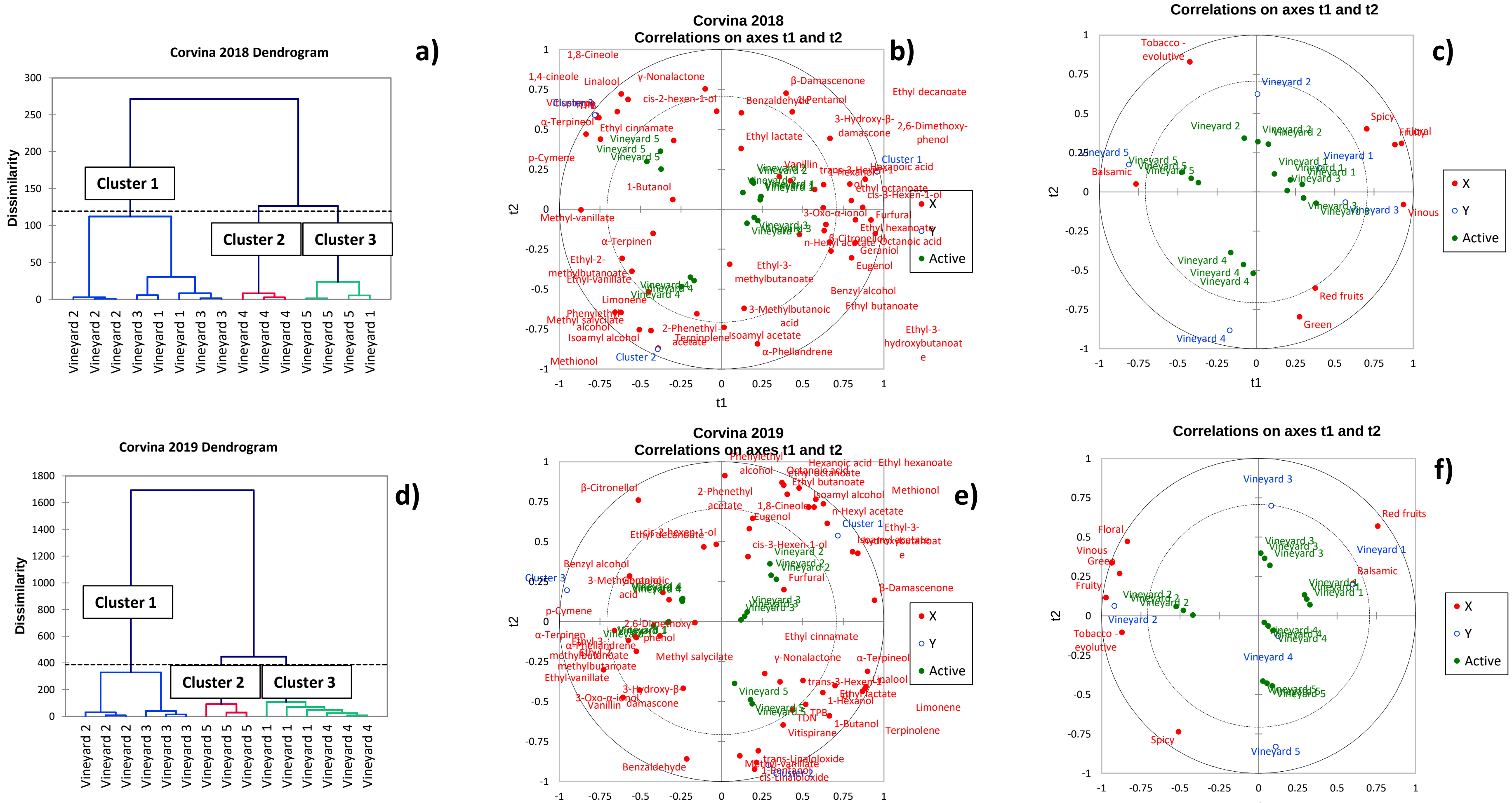


Figure 1.3.2.13. Withered Corvina 2018 a) HCA of sorting task data b) PLS-DA analysis of volatile chemical data referred to sensory clusters c) PLS-DA of aroma series and withered Corvina 2019 d) HCA of sorting task data e) PLS-DA analysis of volatile chemical data referred to sensory clusters f) PLS-DA of aroma series

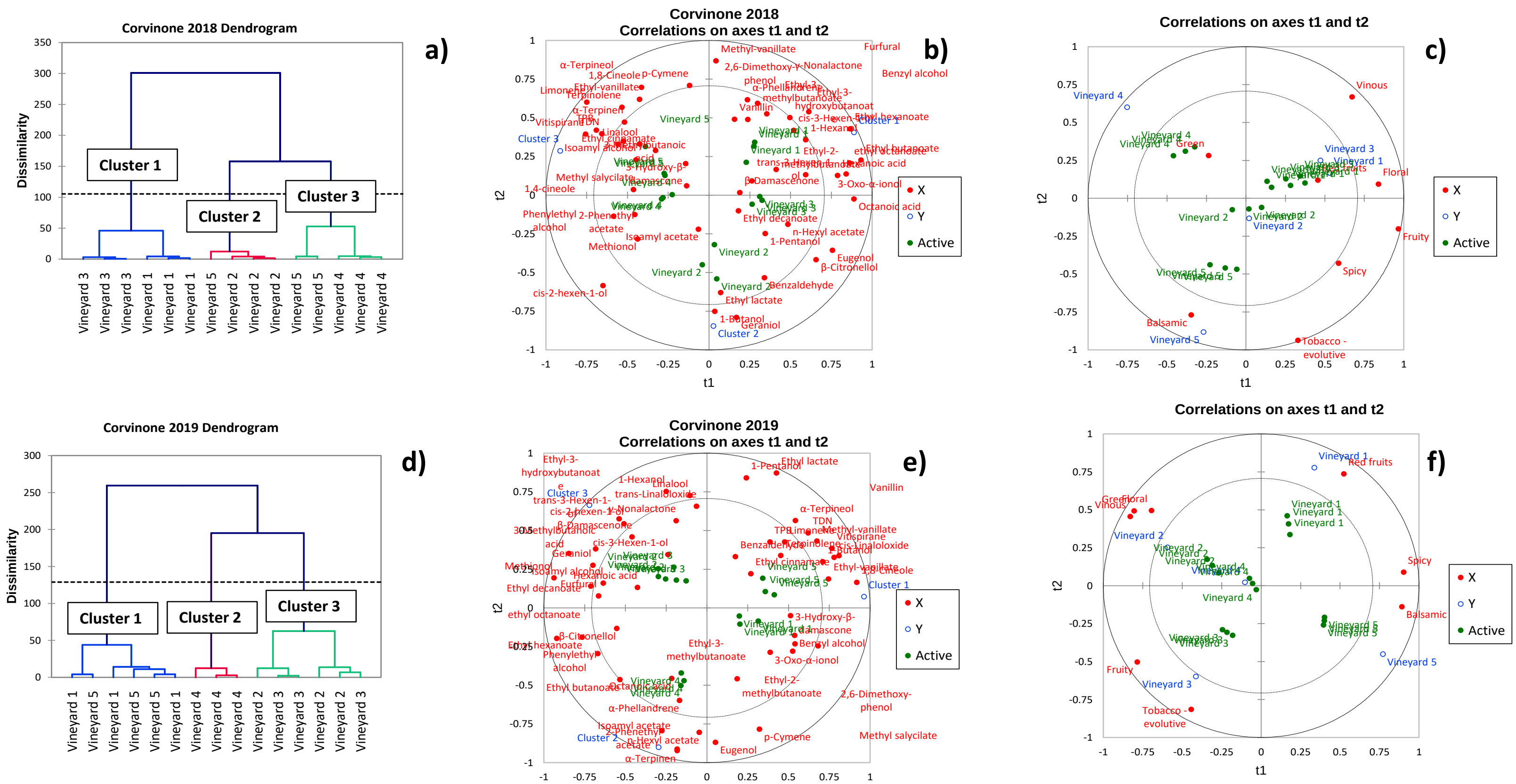


Figure 1.3.2.14. Withered Corvinone 2018 a) HCA of sorting task data b) PLS-DA analysis of volatile chemical data referred to sensory clusters c) PLS-DA of aroma series and withered Corvinone 2019 d) HCA of sorting task data e) PLS-DA analysis of volatile chemical data referred to sensory clusters f) PLS-DA of aroma series

1.4. Conclusion

- Analysis of volatile composition showed clear diversity associated with individual vineyards, supporting the view that the site of grape origin is an important driver of wine aroma composition
- Varietal volatile profiles of Corvina and Corvinone showed wide differences. Corvina was found to be richer in terpenes, some benzenoids, ethyl esters. Conversely, Corvinone was richer in norisoprenoids and C_6 alcohols. Corvina could be more likely associated with floral, balsamic, red fruit attributes, while Corvinone could exhibit more likely green and tobacco-evolutive attributes.
- Among vintage, grape variety, and vineyard of grape origin, vintage had major influence on volatile composition. Nevertheless, independent rescaling of the data from each vintage as a pre-treatment for multivariate analysis proved to be a good strategy to overcome vintage effect. Clear volatiles chemical patterns were observed, representing the unique aroma chemical signature of the geographical origin of each wine.
- The main drivers associated with vineyards typicality were terpenes and norisoprenoids. Among them linalool, α-terpineol, vitispirane, β-damascenone, TPB and TDN played a major role, but other compounds belonging to the classes of benzenoid, C_6 alcohols, branched chain ethyl esters and acetate esters also contributed. Although these compounds were observed in patterns characteristic of wine geographical origin, quantitative ranges of individual compounds varied largely with vintage.
- The recurrence of chemical patterns behind aroma chemical signature of the wines did not result in recurring patterns of odor similarity. Patterns of odor similarities were however observed, and in the case of wines from fresh grapes they indicated a recurring association between geographical origin and aroma compounds such as linear and cyclic terpenes, esters or norisoprenoids. Less clear results were obtained for wines from withered grapes.
- The identification of clear aroma signatures that, beyond the influence of vintage, are associated with specific volatile compounds provides useful information to define grape growing and winemaking practices aimed at enhancing expression of wine sense of place

Chapter 2

Grape compositional factors affecting wine aroma chemical signature and influence of withering

2.1. Introduction and aim

With the exclusion of aromatic varieties such as Muscats, grapes are almost odourless. It is only through the winemaking process, that grapes express their aromatic characteristics. Yeasts and grape enzymes as well as the acid medium contribute to this. However, grapes contain free aroma compounds, although to much lower concentrations than those found in wine. They also contain precursors, mainly glycosidic, which constitute the aroma potential of grapes. The first aim of this section was to investigate grape compositional features that contribute to wine chemical signatures.

Valpolicella is characterized by a wide use of the technology of grape drying for the production of two red passito wines. Both recognized as PDOs, "Recioto della Valpolicella" is a sweet wine, while the most famous “Amarone della Valpolicella” is a dry red. According to their production regulation, grapes sugar content must reach a potential alcohol content of 14% (v/v) because of the withering process before they can be employed for winemaking purpose (DG PQAI-PQAI 04, 2019). This process can last up to 120 days, and is carried out in special facilities called fruttaio, large breezy lofts, where air is continuously exchanged (Paronetto, 1991).

During withering process physical, physiological, and biochemical changes have been identified, suggesting an influence on both environmental parameters and grape-related factor (Barbanti, *et al*., 2008) (Tonutti, *et al*., 2013). During this study, withering was performed in the same fruttaio, so we can consider the environmental parameters within each vintage as of less interest.
The second aim of this section of the work was to investigate the effect of withering on the composition of the different grapes across different vintages. As previously discussed, withering is more than a simple concentration due to water loss, as patterns of gene expression are deeply modified in this phase (Zenoni, *et al*., 2016). In particular, for the purpose of our work, variations in the content of free and glycosidically-bound compounds that were identified as important markers of aroma chemical signatures related to wine geographical origins were studied, including terpenes, norisoprenoids, benzenoids and C_6 alcohols. A thorough comparison will be carried out on grapes, because, in order to reproduce the most commonly used winemaking protocols, different yeasts were used to inoculate fermentations of withered grapes compared to fresh grapes. Therefore, comparison of wines would have been biased by the yeast variable, while the effect of yeast will be investigated more in detail in the following chapter.

2.2. Materials and methods

2.2.1. Grape aroma extracts

Grapes used for winemaking (**Chapters 1.3.1** and **1.3.2)** were also submitted to an experimental protocol aiming at extracting grape volatile compounds and precursors under conditions similar to those occurring during winemaking, but without the action of yeast. Grapes were destemmed and the berries randomized to obtain batches of 2 kg each. From each batch, eight hundred grams were taken, hand crushed with 80 mg of potassium metabisulphite and put into 1.5 L glass bottles altogether with 141 mL of ethanol. To inhibit fermentations 500 µg/L of dimethyl dicarbonate (DMDC) were added as reported by Delfini, *et al*., (2002). Bottles were closed with screw caps and kept at 22 ± 1 °C for 14 days, during which they were hand stirred two times per day without opening the caps. Afterwards, the grapes were pressed with a five litres basket press and the must obtained was supplemented with potassium metabisulphite until a final free SO_2 concentration of 25 mg/L. Macerates were then clarified by centrifugation at 4500 rpm for 15 minutes at 5° C (Avanti J-25, Beckman Coulter, California, USA) and bottled in 330 mL glass bottles with crown caps.

2.2.2. SPE extraction of free and glycosidically-bound volatile compounds and GC-MS analysis

For quantification of free alcohols, esters, fatty acids, benzenoids SPE extraction followed by GC-MS analysis was used, following the procedure described by Slaghenaufi, *et al*., (2019). 100 µL of internal standard 2-octanol (4.2 mg/L in Ethanol) are added to samples prepared with 50 mL of wine and diluted with 50 mL of deionised water. Samples were loaded on a BOND ELUT-ENV, SPE cartridge, (Agilent Technologies. USA) previously activated with 20 mL of dichloromethane, 20 mL of methanol and equilibrated with 20 mL of water. After sample loading, the cartridges were washed with 15 mL of water. Free volatile compounds were eluted with 10 mL of dichloromethane, and then concentrated under gentle nitrogen stream to 200 µL. GC–MS analysis were performed as reported in ***Chapter 1- SPE-GC-MS* analysis**. After SPE elution of free volatile compounds glycosidic precursors were eluted with 20 mL of methanol and collected. Enzymatic hydrolysis of glycosidic precursor was performed as described by Slaghenaufi *et al*. (2019). Glycosidic extracts were evaporated under vacuum thanks to Rotavapor (Buchi R-215 Rotavapor System), recovered with 5 mL of citrate buffer (pH 5), 100 mg of polyvinylpolypyrrolidone (PVPP) and 200 µL of enzyme solution AR2000 (70 mg/mL in citrate buffer) were added. Samples were stored at 37 ºC overnight. Aglycones were extracted and quantified as free volatile compounds with the SPE-GC-MS protocol.

2.2.3. SPME-GC-MS analysis.

For quantification of free terpenes, norisoprenoids and methyl salicylate SPME extraction followed by GC-MS analysis was used as reported in ***Chapter 1- HS-SPME-GC-MS*** **analysis**

2.2.4. Summary of studied grapes

In the following table are summarized the grapes studied during this chapter.

Table 2.2.1. Summary of studied grapes

Vineyards	Varieties	Vintages	Grape treatments
V1-V2-V3-V4-V5	Corvina and Corvinone	2017-2018-2019	Fresh and withered

2.2.5. Statistical analysis

Principal Component Analysis (PCA), Mann-Whitney test (α=0.05) and Correlation Analysis of chemical data have been performed using XLSTAT 2017 (Addinsoft SARL, Paris, France).

2.3. Results and discussion

2.3.1. Grape compositional features determining wine aroma chemical signatures

Corvina and Corvinone are non-aromatic grape varieties, and therefore in the corresponding wines grape-related aroma compounds arise from the transformation of different aroma precursors, in particular glycosidic ones (Slaghenaufi *et al*. 2019). These aroma compounds, in conjunction with the ones produced by the yeast during fermentation, contribute to perceived aroma. The data provided so far showed that various terpene alcohols, norisoprenoids, benzenoids, and esters contribute primarily to defining specific aroma chemical and sensory signatures that can be associated with the site of grape origin. The question arise therefore as to which are the compositional features of the grapes that underpin wine aroma chemical signatures.

Initially, the presence of an aroma chemical signature already in the grapes was assessed analysing the volatile compounds and precursors in the macerates obtained from the grapes of each vineyard in the absence of yeast activity. In the case of fresh grapes, PCAs performed with the same modalities used in wines, showed a certain degree of differentiation (**Figure 2.3.1.1**). It can be therefore inferred that an aroma chemical signature can be already observed when the grapes are left to macerate in the absence of yeast activity. In general, these signatures were less defined than those of the corresponding wines, due to the lack of yeast action on varietal compounds (e.g., biotransformation of geraniol in β-citronellol) as well as the fact that fermentative compounds, esters in particular, were present in rather small amounts, as it is usually the case for grapes.

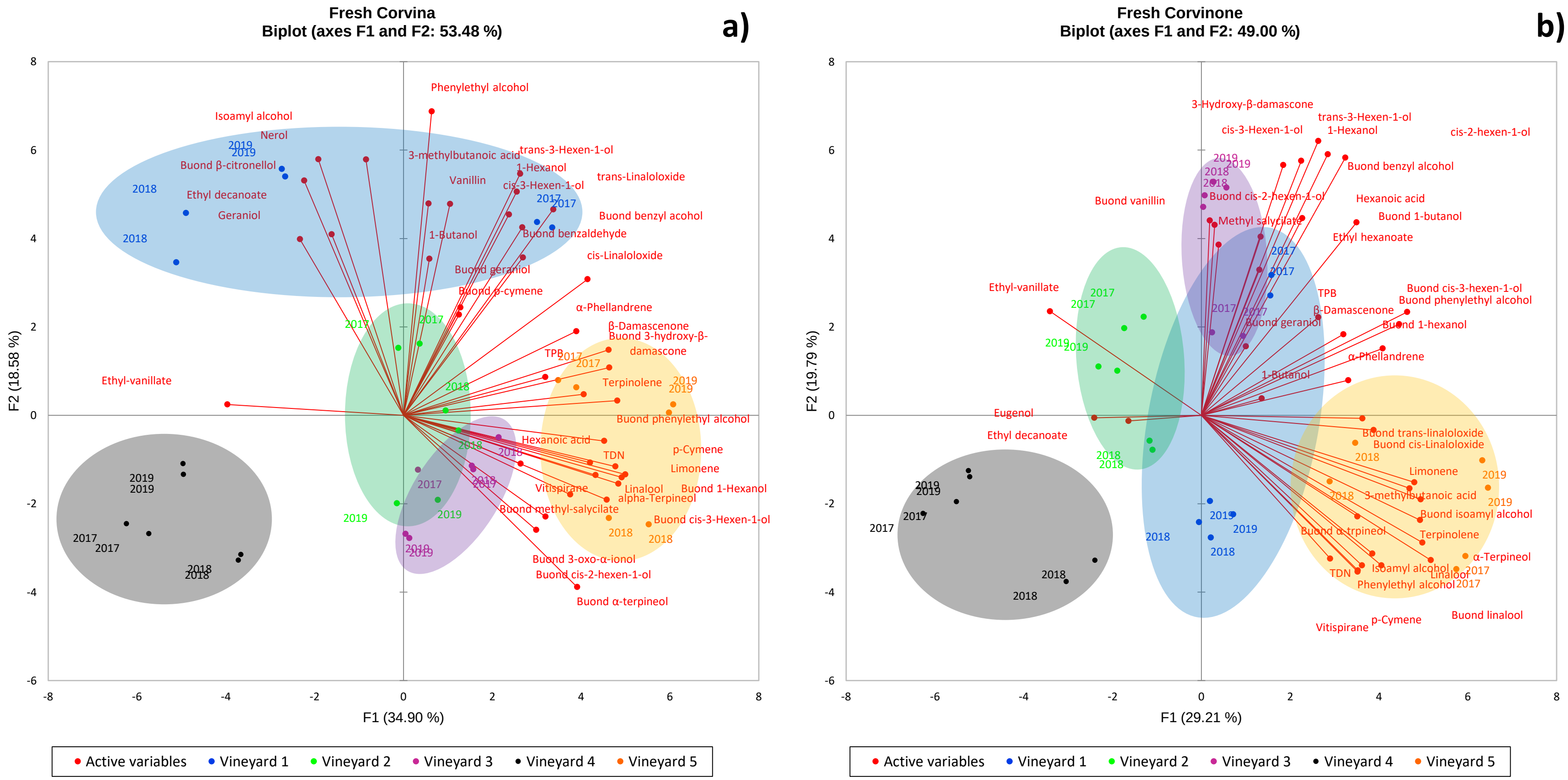


Figure 2.3.1.1. PCA of significantly different free and bound volatile compounds of fresh a) Corvina and b) Corvinone fresh grapes vintage rescaled (from 0 to 100). Circles are not the result of statistical processing but are useful for a better understanding of the plot

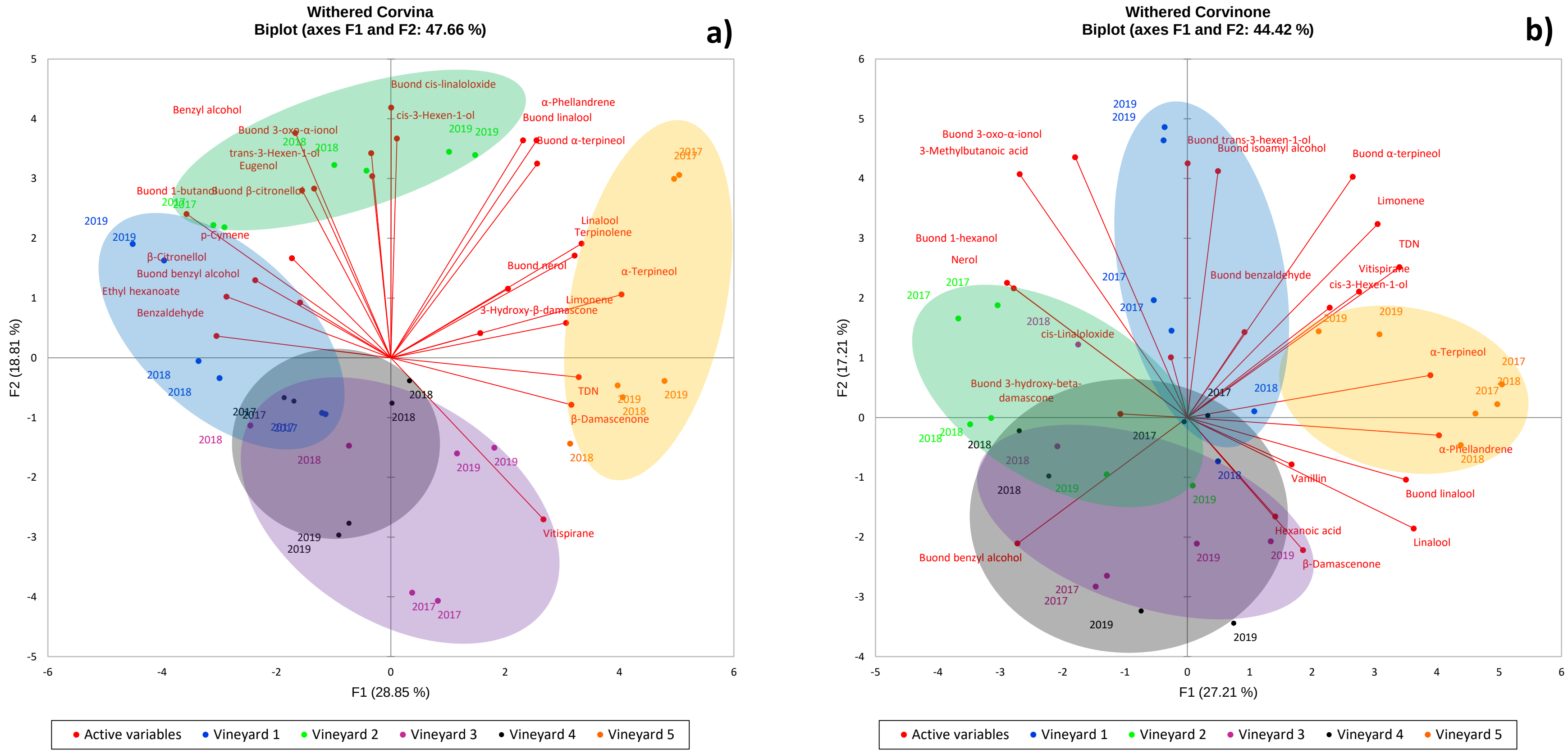


Figure 2.3.1.2. PCA of significantly different free and bound volatile compounds of withered a) Corvina and b) Corvinone fresh grapes vintage rescaled (from 0 to 100). Circles are not the result of statistical processing but are useful for a better understanding of the plot

As in the case of wines, terpenes (including bound forms) were found to contribute significantly to the differences observed. As grapes were harvested and processed at different degrees of maturity, it could be argued that the differences in volatile compounds were due simply to a different sugar ripeness degree. Of course, sugar ripeness could have played a role, but differences cannot be attributed only to this factor. Total terpenes and norisoprenoids, as well as the majority of individual compound did not show any correlation with glucose + fructose content at harvest **(Figure 2.3.1.3** and **Appendix 2.3.1)**

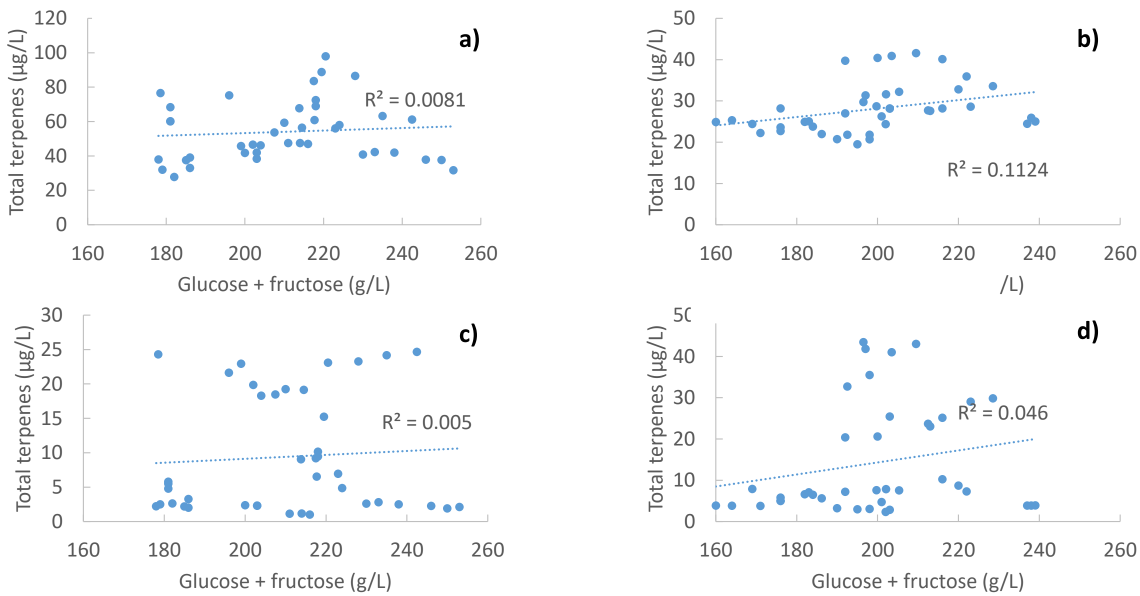


Figure 2.3.1.3. Correlations between glucose+fructose content in grapes and total terpenes content in a) Corvina and b) Corvinone wines and between glucose+fructose content in grapes and total norisoprenoids content in c) Corvina and d) Corvinone wines

For instance, in Corvina, in vintage 2019, V1 and V2 showed the same glucose+fructose content in grapes, 182.3 g/L and 181 g/L respectively, but V2 showed double content of terpenes and norisoprenoids compared to V1. The same was found in Corvinone, in vintage 2017 V1, V2 and V3 grapes showed the same glucose+fructose content but very different terpenes (40.07 µg/L, 21.80 µg/L, 30.53 µg/L) and norisoprenoids (20.49 µg/L 34.12 µg/L and 42.63 µg/L) levels. Slaghenaufi *et al.*, (2019), in wines produced with Corvina grapes of different ripeness, found a greater influence of the vineyards on terpenes and norisoprenoids content compared to sugar ripeness too.

Furthermore, although both clone and rootstock can influence grape and wine volatile composition, in our case all parcels had the same clone/rootstock combination, so that this factor could not be considered as a major driver of the observed diversity. Apart from, as reported above, a possible effect of temperature and sum of rainfall on the vintages, poor correlations have been found between the content of total terpenes and norisoprenoids and the monthly average temperature (C°) and sum of rains (mm), in June, July and September before harvesting, particularly with regard to the origin of grapes.

The observation that difference in grape maturity were not primarily associated with aroma chemical signatures lead to various interesting considerations. First, vintage decisions related to harvest date in response to grape maturity, albeit important for overall wine quality, did non impaired the ability of individual vineyard to express their unique aroma signature. Second, more complex compositional features should be present in the grapes, that lead to the development of specific wine compositional profiles associated with geographical origin. To address this second and very important point, various correlations between grape and wine composition were explored, focusing on compounds that contributed primarily to single vineyard wines aroma signatures. For example, grape levels of linalool were extremely well correlated with wine linalool and α-terpineol content **(Figure 2.3.1.4** and **Appendix 2.3.1.2)**. Free limonene in wines was correlated with free α-terpineol in grapes (R^2=0.754 and R^2=0.725). These observations reflect probably the complex network occurring during grape maceration in an acid environment, resulting in the release of terpenes in the macerates that will then contribute to terpene profile of the wines.

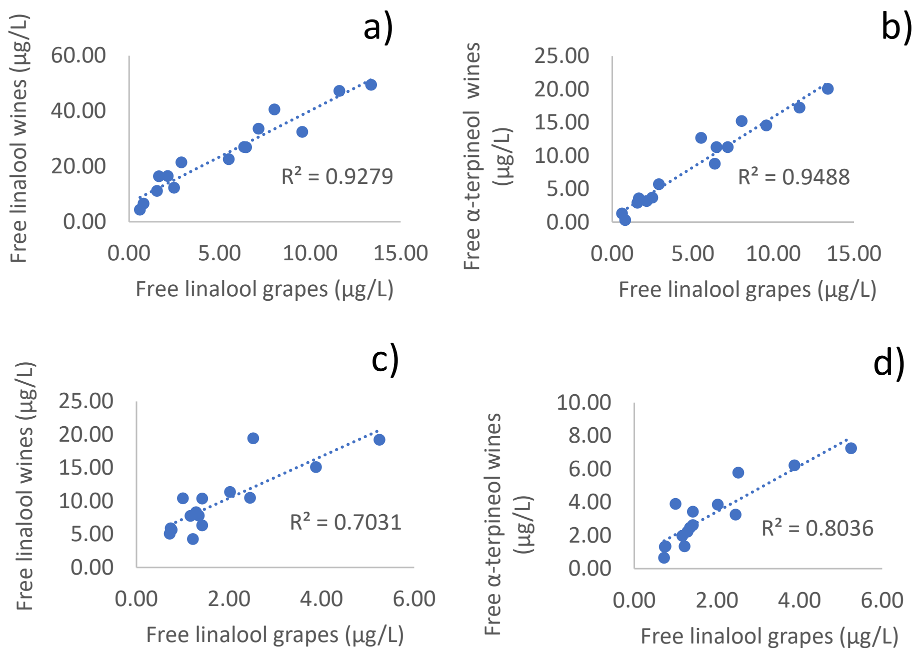


Figure 2.3.1.4. Correlations between a) Corvina free linalool in grapes and free linalool in wines b) Corvina free linalool in grapes and free α-terpineol in wines c) Corvinone free linalool in grapes and free linalool in wines d) Corvinone free linalool in grapes and free α-terpineol in wines.

They also provide correlations provide interesting clues concerning the possibility to monitor, and to some extent predict, wine volatile composition and typicality from analytical parameters of the grapes. However, one important point that needs to be specified is that terpene levels in the wines were always much higher than in the corresponding macerates, due to the fact that yeast enzymatic activity represents a major factor of release of terpenes from glycosidic precursors. From this point of view, taking linalool as an example, good correlations were obtained between the pool of linalool in the grapes (free + bound) and the amount of linalool in the wines (**Figure 2.3.1.5**), in particular for Corvina. Overall, it can be concluded that the terpene component of wine aroma signatures is reasonably well correlated with grape content of free terpene and glycosidic precursors.

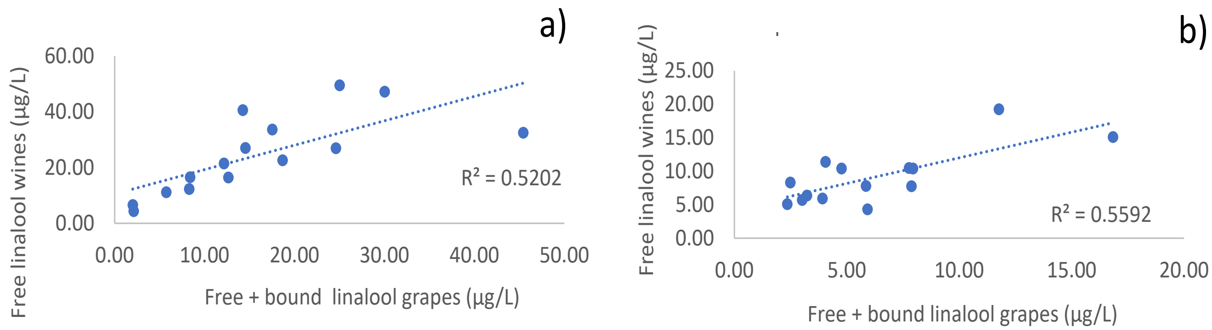


Figure 2.3.1.5. Correlations between total (free + bound) linalool in grapes and free linalool in wines in a) Corvina and b) Corvinone

Also in the case of withered grapes it could be argued that wines differences in terpenes ad norisoprenoids contents were due to different ripeness levels or to different concentration due to water loss (Boss, *et al*., 2014) (Marais, *et al*., 1992). Also in this case, however, no correlations were found. For instance, considering 2017 Corvinone V1 and V3 grapes had the same glucose + fructose content both before and after drying but significant differences in terpenes and norisoprenoids have been found (**Appendix 1.4.1**, **1.4.5-1.4.11**).

Correlation studies concerning terpenes (**Figure 2.3.1.6-2.3.1.7** and **Appendix 2.3.1.3**) highlighted that grape levels of bound linalool were correlated with wine free linalool and α-terpineol content. Other correlations were set between free limonene in wines and free linalool and α-terpineol in Corvina (R^2=0.718 and R^2=0.572) and Corvinone (R^2=0.414 and R^2=0.520). In Corvina free p-cymene in wines and grapes set very high correlation (R^2=0.941).

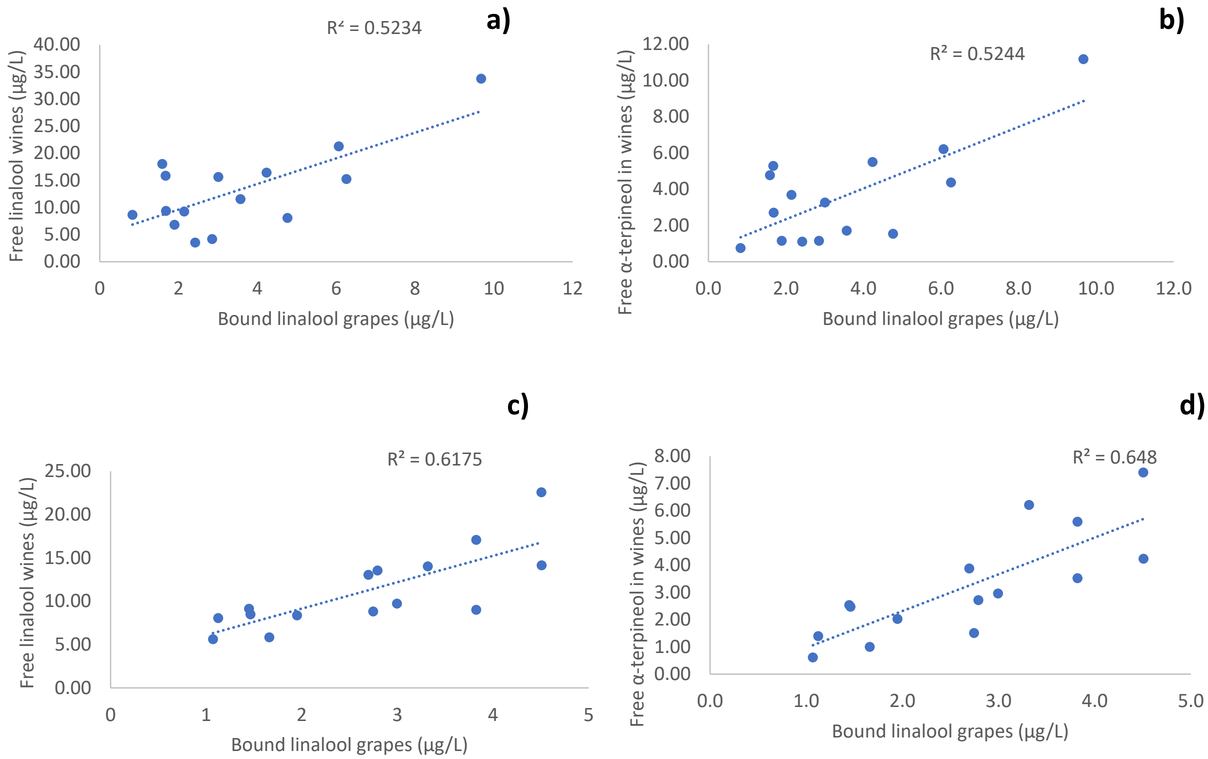


Figure 2.3.1.6. Correlations between withered a) Corvina bound linalool in grapes and free linalool in wines b) Corvina bound linalool in grapes and free α-terpineol in wines c) Corvinone bound linalool in grapes and free linalool in wines d) Corvina bound linalool in grapes and free α-terpineol in wines.

As in fresh grape, also in withered grapes, terpene levels in the wines were higher than in the corresponding macerates. Again, good correlations were obtained between total linalool in the grapes (free + bound) and the levels of free of linalool in the wines, especially in Corvinone (**Figure 2.3.1.7**).

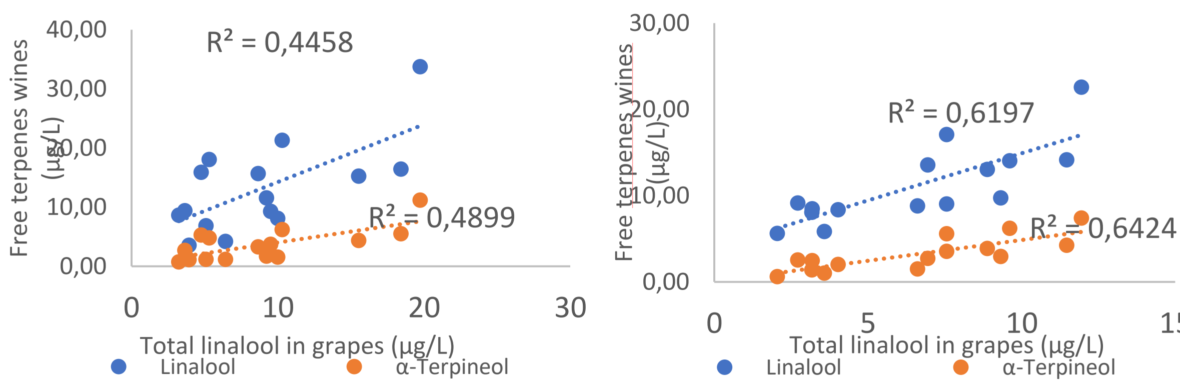


Figure 2.3.1.7. Correlations between total (free + bound) linalool in grapes and free linalool and α-terpineol in wines in withered a) Corvina and b) Corvinone

Esters were another group of volatile compounds contributing to aroma chemical signatures, in particular isoamyl acetate and acetate esters as well as branched-chain ethyl ester. Although small amounts of these compounds were found in the grapes, the origin of these compounds is in large part fermentative. Acetate esters in wine are related to amino acid content of grape must through the Erlich pathway, and their concentration is strongly modulated by the amount of yeast assailable nitrogen (Ugliano, *et al*., 2008), (Ugliano, *et al*., 2010). In our study, YAN content was not modified by any addition, and in fresh grapes wines it varied in a rather wide range in both Corvina (57.7 mg/L – 197.7 mg/L) and Corvinone (65 mg/L – 214.7 mg/L), reflecting naturally occurring fluctuations. Wine isoamyl acetate content was very well correlated with grape YAN content, in particular in Corvina (**Figure 2.3.1.8**), with a R^2=0.7069. A relationship was observed in Corvinone too, although in this case two different trends were observed, one involving V1 and V4 (R^2=0.5993) and second involving V2, V3 and V5 (R^2=0.7216). Some outliers were observed in all cases, corresponding to vineyards that, based on grape YAN content, resulted in wines with too much or too little isoamyl acetate.

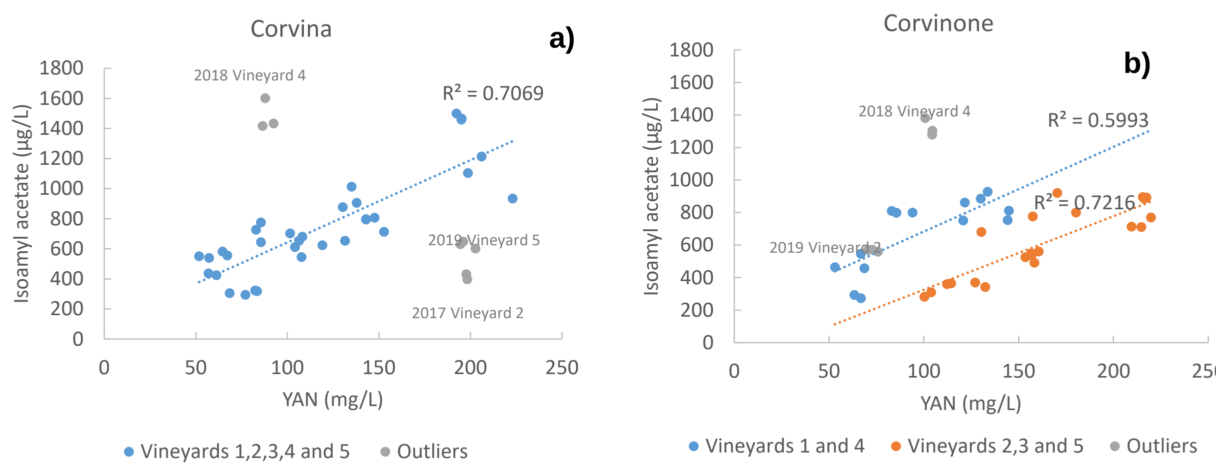


Figure 2.3.1.8. Correlation between YAN and Isoamyl acetate in a) Corvina and b) Corvinone fresh grapes wines.

Also, worth consideration was the fact that V4 was consistently an outlier, displaying higher isoamyl alcohol content than its YAN value would indicate. V4 is terraced and trained with pergola system. Zoecklein *et al*. (2008) found significant different content of isoamyl acetate according to the training system, and unsaturated fatty acid are also influenced by training system (Xu, *et al*., 2015). According to Antalick *et al*. (2015) unsaturated fatty acid could play a role repressing alcohol acetyltransferase expression, which could represent an additional source of specificity.

In the case of wines from withered grapes, comparison of must nitrogen levels, which showed differences between musts up 180 mg/L, and wine esters content confirmed the existence of correlations between isoamyl acetate and YAN content with some outliers (**Figure 2.3.1.9**). V1 and V4 and V2, V3 and V5 established different correlation with high coefficient of correlation (R^2 between 0.57 and 0.87). V4 in Corvinone showed again as an outlier and, as previously postulated, the training system could have played role modulating the content of unsaturated fatty acids. No correlation was observed for other esters in fresh and withered grapes (**Appendix 2.3.1.4** and **2.3.5**)

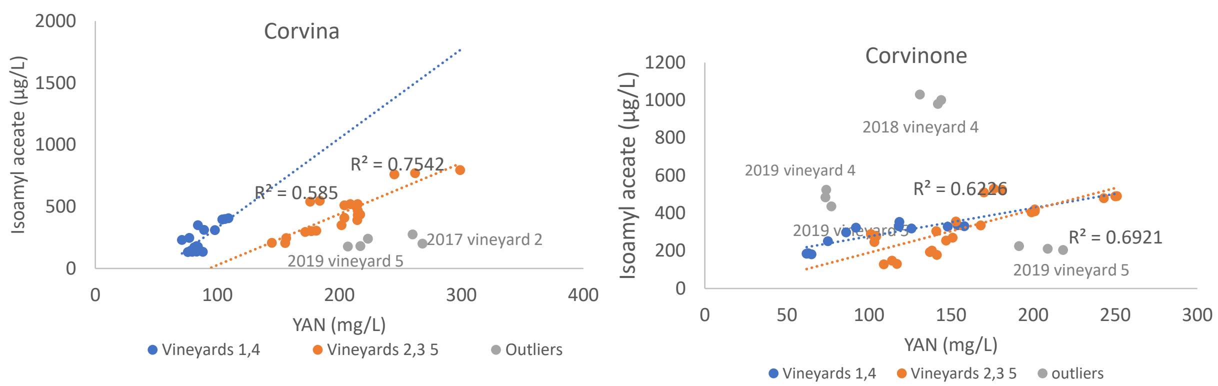


Figure 2.3.1.9. Correlation between YAN and Isoamyl acetate in a) Corvina and b) Corvinone withered grapes wines

Because YAN is not a direct precursor of isoamyl acetate, but rather a parameter influencing its production by yeast, these observations support the view that grape YAN should be considered in itself a component of the expression of wine sense of place, identity, *terroir*, etc. Accordingly, since YAN levels in grapes were due to intrinsic composition of grape, and this led, in particular in Corvinone, to specific pattern, this could be considered as a further vineyard signature. This observation implies indirectly that addition of yeast nitrogen nutrients, in particular diammonium phosphate (DAP) can weaken the connection between wine aroma and its sense of place. On the other hand, the lack of YAN can make the yeast use sulphur amino acids, cysteine and methionine, resulting in the release of hydrogen sulphite and mercaptans leading to the appearance of reduction off-flavour (Jiranek, et al., 1995) and therefore resulting in a decrease of wine "sense of place". The choice of the right compromise is therefore an appropriate challenge for "varietal enology".

2.3.2 Withering effect on grapes aroma composition

2.3.2.1. Overview of Grape volatile chemical profile

Concentration of free and bound compounds in fresh and withered grapes are shown in **Appendix 2.3.2.1-2.3.2.12.** PCAs of fresh and withered grapes, obtained using all free and bound volatile compounds, confirmed that vintage was a major differentiating factor, separating samples mainly on PC1, while the varieties on the PC2 (**Figure 2.3.2.1** and **2.3.2.2**). In both fresh and withered grapes vintages 2018 was well differentiated from the other two vintages, which were partially overlapped. From a chemical point of view, differently from wines (**Figure 1.3.1.1** and **1.3.2.1**), grapes differences between vintages were smaller. 2018 fresh grapes showed 35% and 41% less mean total free terpenes compared with the other two vintages. Concerning bound compounds Corvinone 2017 showed slightly lower mean total bound terpenes, while no significant differences were found in Corvina. Variations in temperatures and rainfall across the three vintages (see **1.3.2-*Overview of different vintages volatile chemical profiles***), are likely to have induced the observed compositional changes, for example warmer climate and limited water availability can influence terpenes content (Alessandrini, *et al*., 2016) (Koundouras, *et al*., 2006) (Qian, *et al*., 2009). Vintage 2018 was in fact characterized by lower temperatures and higher rainfall in August and September. However, it should be taken into account that the prolonged maceration (fourteen days) applied in the preparation of the grape macerates induced not only the extraction of volatile compounds but also acid catalysed reactions, such as the hydrolysis of glycosidic precursors.

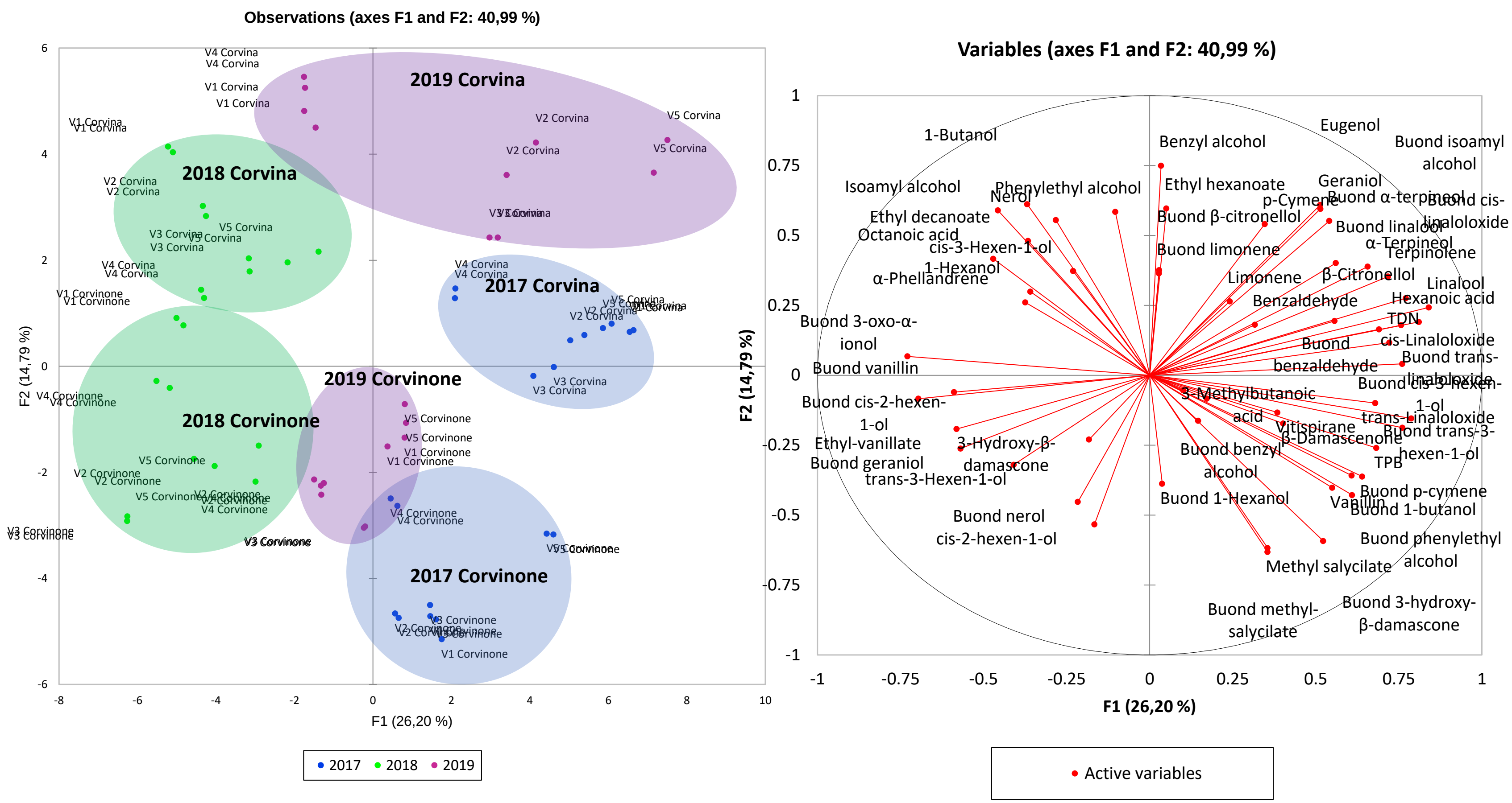


Figure 2.3.2.1 PCA analysis of free and bound volatile compounds of all fresh Corvina and Corvinone grapes. V1-V5 is short for vineyard 1-vineyard 5. Circles in observations plot are not the result of statistical processing but are useful for a better understanding of the plot

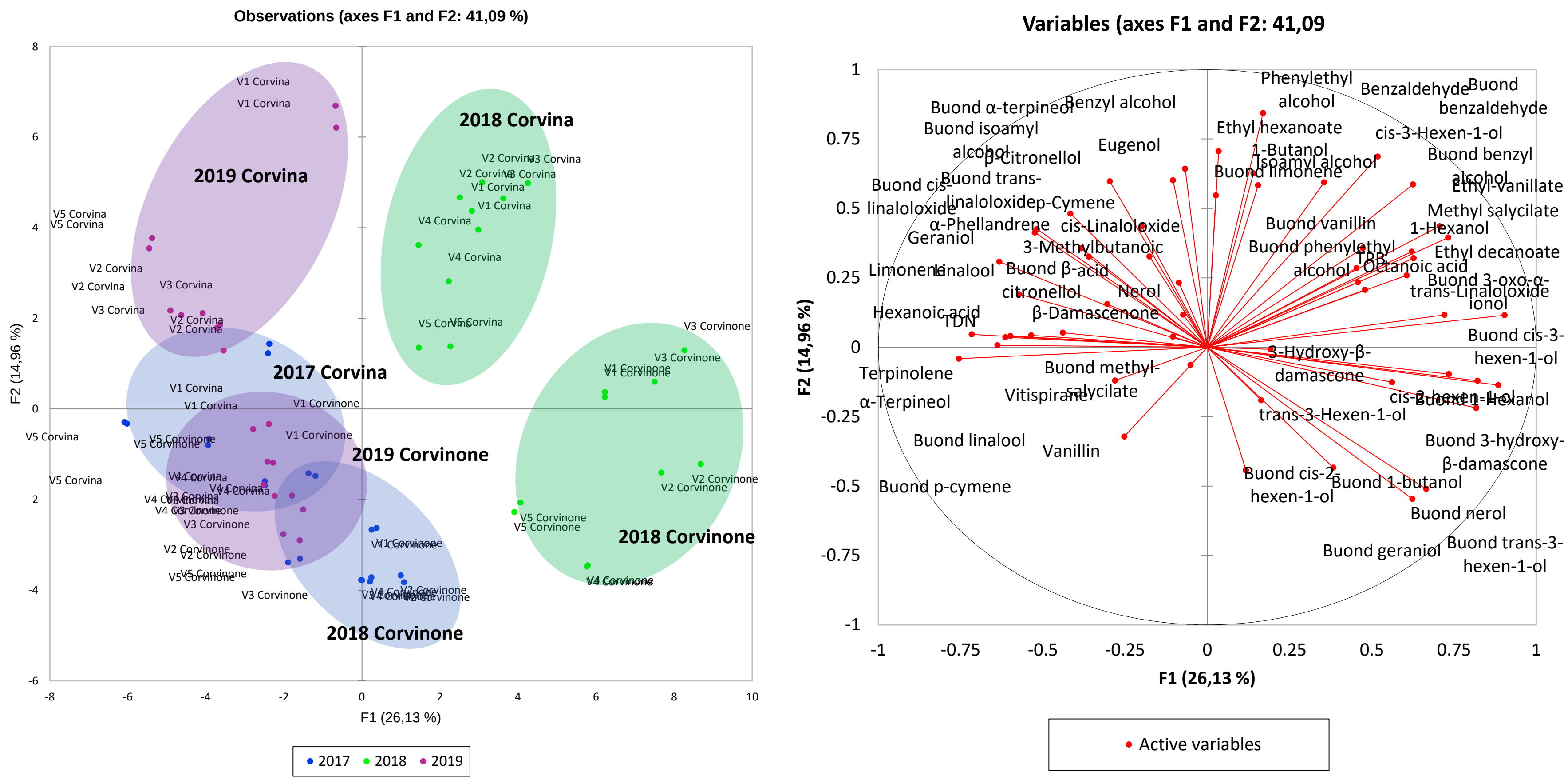


Figure 2.3.2.2 PCA analysis of free and bound volatile compounds of all withered Corvina and Corvinone grapes. V1-V5 is short for vineyard 1-vineyard 5. Circles in observations plot are not the result of statistical processing but are useful for a better understanding of the plot

2.3.2.2. Influence of withering on volatile chemical profile of fresh grapes

Variations of individual compounds in response to withering followed complex patterns (**Appendix 2.3.2.1-2.3.2.13**) and a detailed investigation will be beyond the purposes of this study. However, bearing in mind that our goal was to rationalize some the relationships between grape composition and wine aroma chemical signatures, it could be useful to consider **Figures 2.4.3** and **2.4.4**, providing an overview of withering effects in Corvina and Corvinone grapes. In both cases, fresh and withered samples were clearly discriminated on PC1. Fresh grapes were characterized by higher content bound terpenes, while withered grapes by higher levels of β-damascenone, various bound benzenoids, and in the case of Corvinone also free linalool. The observation that wines from fresh grapes were characterized by higher terpene content compared to the corresponding withering samples can be therefore explained with the increased content of bound terpenes forms, as free compounds were in some cases even increased with withering. Conversely, the increased norisoprenoid and benzenoid (e.g. vanillates) content of withered wines could depend on higher content of both free and bound forms.

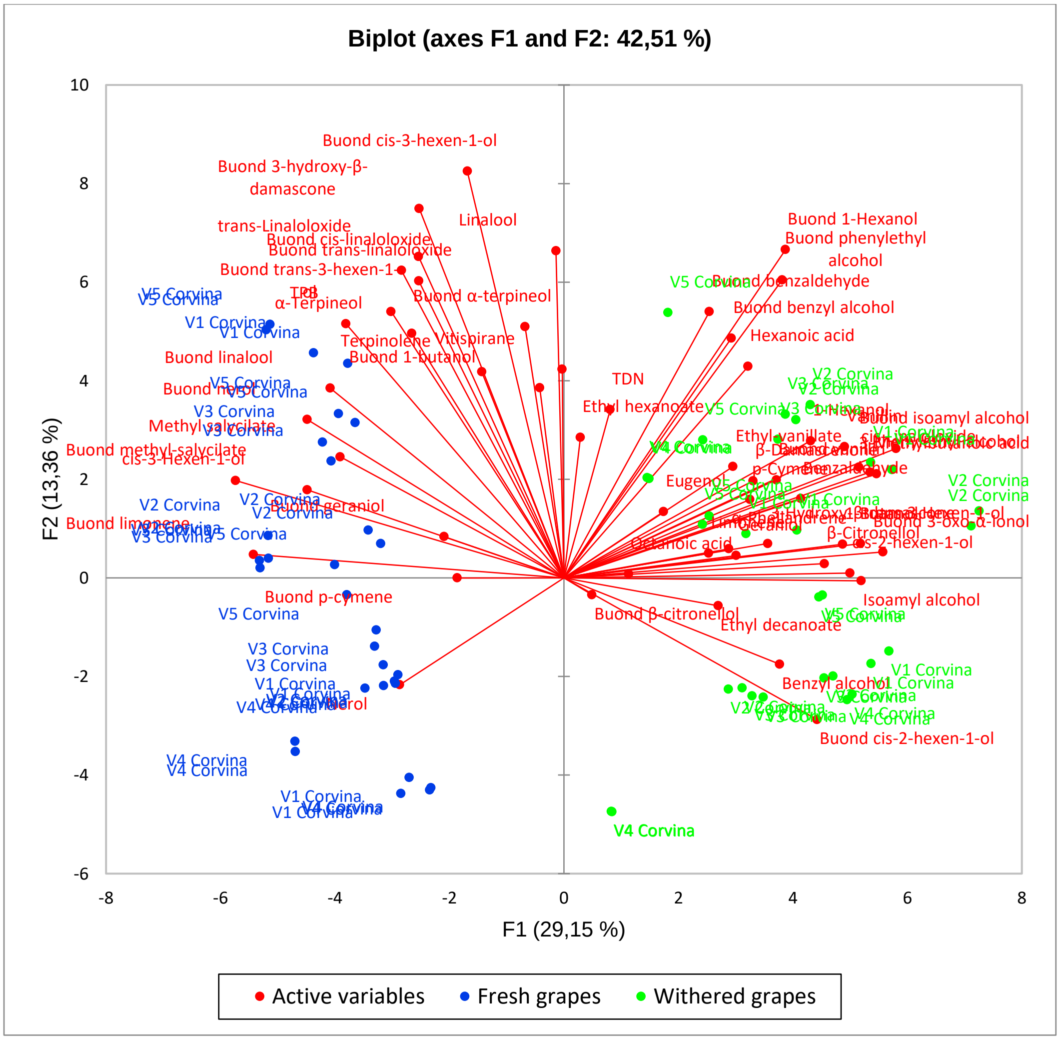


Figure 2.3.2.3 PCA of free and bound volatile compounds of Corvina fresh and withered grapes vintage rescaled (from 0 to 100). V1-V5 is short for vineyard 1-vineyard 5

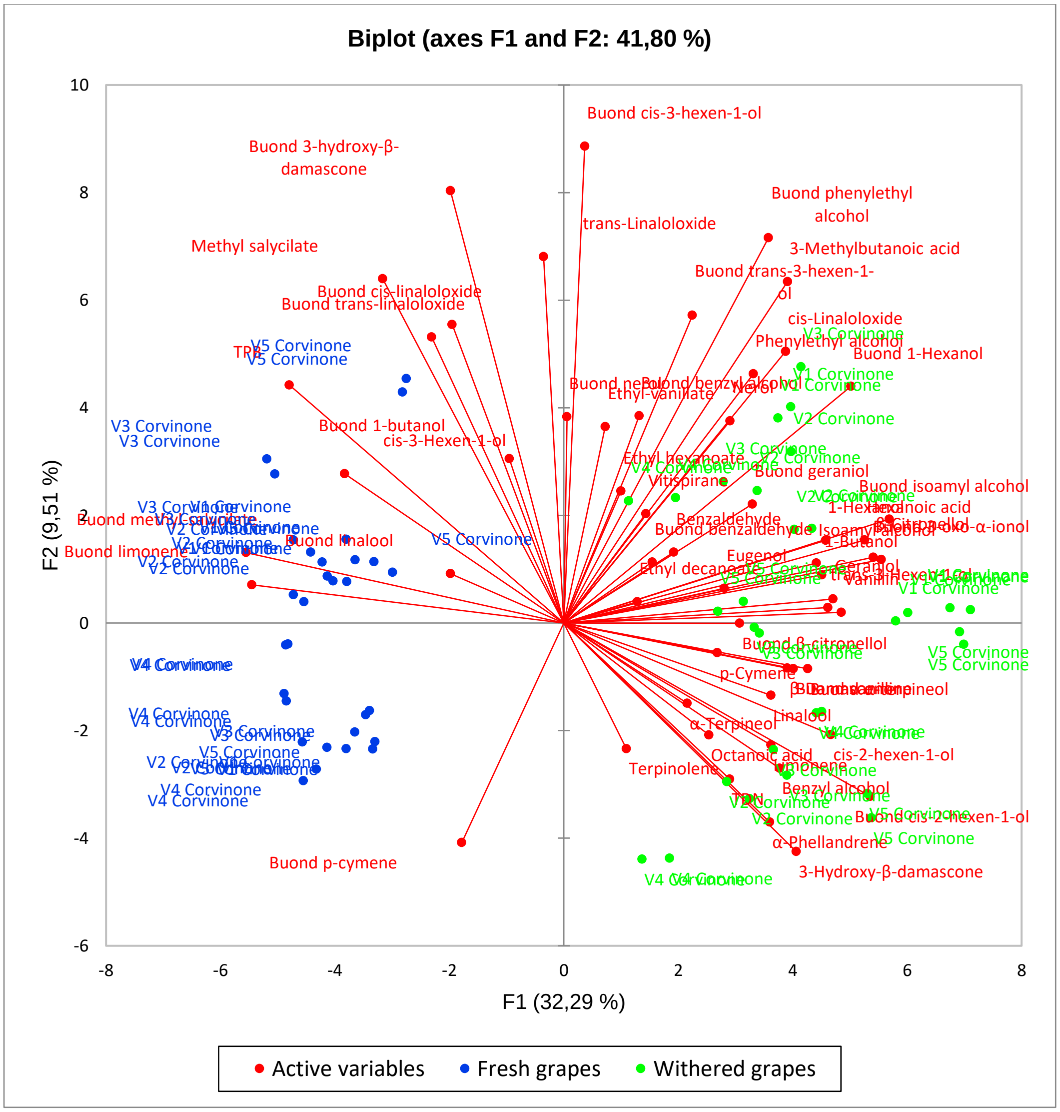


Figure 2.3.2.4 PCA of free and bound volatile compounds of Corvinone fresh and withered grapes vintage normalized. V1-V5 was short for vineyard 1-vineyard 5

Twenty free volatile compounds were found to be statistically different (Mann-Whitney, α=0.05) (**Appendix 2.3.2.13**) between fresh and withered Corvina, while twenty-six in Corvinone. The statistically different bound compounds were instead seventeen and eighteen respectively. Withering treatment had a major impact mainly on terpenes, norisoprenoids and benzenoids.

- Concerning terpenes, Corvina and Corvinone showed different withering patterns. Free terpenes showed different behaviour in the two varieties. In Corvina in two out of three vintages, no differences were found, while in Corvinone in all vintages withering treatment led to increased free terpenes level. Considering the individual terpenes, only free β-citronellol increased systematically in each variety and vintage as also reported by literature (D'Onofrio, 2013). Considering bound terpenes, in Corvina decreased in all vintages, while in Corvinone in two out of three they increased. Bound linalool decreased in all the cases after withering. Bound nerol and geraniol in Corvina decreased while in Corvinone didn't. Increased in bound terpenes levels has been reported in other studies (Ossola, *et al*., 2017), possibly as a concentration effect due to water loss

- Free norisoprenoids were presents in small amounts. Withered grapes showed increased levels, mainly of β-damascenone, about twice the content of fresh grapes in both varieties. Concerning total bound norisoprenoids in most cases increased with withering treatment. Among them 3-oxo-α-ionol showed increasing content in withered grapes, as reported by literature (Giacosa, *et al*., 2019), while 3-hydroxy-β-damascone showed similar or lower content.
- In accordance with literature increased level of free benzenoids after withering was observed in both varieties (Franco, *et al*., 2004) (López de Lerma, *et al*., 2014), among them benzaldehyde, benzyl alcohol, vanillin and eugenol, and although not to a significant degree also of ethyl vanillate. Only free methyl salicylate although in very low concentrations showed higher content in fresh grapes. Increased level of bound benzenoids were found too, as reported by previous studies (Giacosa, *et al*., 2019).
- Other compounds such as free and bound C_6 compounds showed increased levels thanks to withering treatment. Some compounds of mainly fermentative origin such as esters, alcohols and fatty acids, were also found, as reported by other studies (Bellincontro, *et al*., 2004) (Franco, *et al*., 2004) (Ruiz, *et al*., 2009) (D'Onofrio, 2013) (López de Lerma, *et al*., 2014). They were useful to define the metabolic differences even if their contribution was almost negligible. Among them fatty acids and alcohol showed an increase in grapes after withering, while esters didn't.

2.4. Conclusion

- Volatile chemical signatures representative of geographical origin were observed in grapes. Compared to those observed in wines, these signatures were less defined and, in terms of absolute concentrations, individual compounds were well below their odor thresholds.
- Grape compositional features that contribute to wine chemical signatures of geographical origin were
  - Content of free+glycosidically-bound terpenes, which was positively correlated to wine content of free terpenes
  - YAN, which was positively correlated to wine content of isoamyl acetate.

  We propose therefore that YAN is included among grape parameters that contributing to expressing a wine sense of place.

- Withering effects grape volatile composition, in particular decreasing the content of bound terpenes and increasing that of norisoprenoids and benzenoids.

Chapter 3

Influence of grape composition, yeast strain and use of inoculum on aroma profile of Corvina and Corvinone wines from fresh and withered grapes

3.1. Introduction and aim

Wine aroma compounds are often classified according to their origin. This refers to varietal, pre-fermentative, fermentative and post-fermentative aroma compounds. Despite the fact that there is a strong interaction of these sources and it is often difficult uniquely attribute the occurrence of a particular metabolite to one or to another, this classification is useful to define the main variable contributing to wine volatile profile. This chapter investigates the impact that the fermentative stage and in particular the use of different commercial yeast strains and inoculums have on wines produced with grapes of different origins.

Saccharomyces cerevisiae starter cultures are largely used in winemaking to limit the growth of naturally-occurring yeasts and achieve more predictable and desired outcomes (Binati, *et al*., 2020). Different *S. cerevisiae* strain, besides ethanol, glycerol and carbon dioxide, can generate different aroma profiles as a consequence of different ability in the production of fermentative metabolites such as esters, higher alcohols and fatty acids, in releasing varietal volatile metabolites from precursors, as well the capacity to synthesise de novo volatile compounds (Molina, *et al*., 2009). Yeasts have also different capacities to bio transform different varietal metabolites, as for the enzymatic reduction of geraniol in β-citronellol (Slaghenaufi, *et al*., 2020). To date, there is a growing interest for the inoculation of non-*Saccharomyces* yeasts as co-starter in wine production as well as for spontaneous fermentation for their different impact on the aroma profile of wines (Binati, *et al*., 2020). Some studies support the theory that spontaneous fermentations have a positive effect on wine aroma profile enhancing typicality as a consequence of simultaneous growth of different yeast strain and species that are naturally present on the grapes, therefore enhancing the expression of wine sense of place (Francesca, *et al*., 2016). This style of “natural” winemaking, which provides for spontaneous fermentation and avoids the use of chemical addition is gaining importance in the wine market. Differences between yeasts strains and inoculum strategies can be as big as it is possible to produce wines with different compositions from the same grape must and different yeasts. The aim of this chapter was to evaluate the influence of grape origin, different S. *cerevisiae* strains as well as of a spontaneous fermentation on aroma profile and sensory characteristics of Valpolicella red wines.

3.2. Materials and methods

In this chapter the simultaneous influence of yeast and inoculation strategy and grape origin on the metabolic and sensory volatile profile of Valpolicella red wines was evaluated. Results of wines produced with fresh grapes are first presented and then those produced with withered grapes.

3.2.1. Grape Origins and winemaking

Wines were produced with either fresh and withered Corvina (*Vitis vinifera* L. *cv.* Corvina) or Corvinone (*Vitis vinifera,* L. cv. Corvinone). Fresh grapes were harvested in mid-September 2018 in vineyards belonging to the same winery and located in two sub-regions within the Valpolicella area, locally referred to as Valpolicella Orientale (Area 1) and Valpolicella Classica (Area 2). Specifically, for Area 1, grapes were obtained from three vineyard parcel located in the same estate. in the town of Mezzane (45°30'36.7"N 11°08'02.7"E). In the case of Area 2, two vineyard parcels were considered, located at a distance of approximately five kilometres from each other, in the towns of San Pietro in Cariano (45°30'40.5"N 10°54'58.6"E) and San Giorgio in Valpolicella (45°32'16.6"N 10°51'19.4"E) respectively. The grapes of these two parcels were pooled together to have a single vinification batch, as regularly done in the winery. After harvesting a part of the grapes was destined for winemaking and a part was destined to withering treatment, carried out by the conferring winery.

For winemaking grapes were destemmed and the berries randomized to obtain batches of 20 kg each. From each batch, eight hundred grams were taken, hand crushed with 80 mg of potassium metabisulphite and put into 1.5 L glass vessel. Analytical parameters of the musts are provided in **Appendix 3.3.1.1**. Fermentations were carried out in duplicate with four different commercial yeasts, *Saccharomyces cerevisiae x Saccharomyces kudriavzevi* AWRI 1503 (**Yeast 1**) (AB Mauri, Camellia, Australia), *Saccharomyces cerevisiae* AWRI 796 (**Yeast 2**) (AB Mauri, Camellia, Australia), *Saccharomyces cerevisiae* Zymaflore® *XPURE* ***(Yeast 3)*** (Laffort, Floirac, France)**,** *Saccharomyces cerevisiae* Zinfandel (**Yeast 4)** (Vason, Verona, Italy). Active dry yeast of each commercial starter was rehydrated in water at 37°C for 15 min, then 1.6 mL of each culture (100 g/L) was used to inoculate individual grape batches. A fifth experimental modality was also prepared, consisting of a spontaneous fermentation **(Spontaneous).** For this modality, no potassium metabisulphite was added at berry crushing. Fermentations were carried out at 22 ± 1°C, with cap being broken twice a day by gently pressing it down skins with a steel plunger and density and temperature monitored daily. Upon completion of alcoholic fermentation (glucose-fructose < 2 g/L), wines were pressed with a ten litres basket press and supplemented with potassium metabisulphite until a final free SO_2 concentration of 25 mg/L. Wines were then clarified by centrifugation at 4500 rpm for 15 minutes at 5° C (Avanti J-25, Beckman Coulter, California, USA) and bottled in 330 mL glass bottles with crown caps, with free SO_2 concentration of 25 mg/L.

3.2.2. Summary of studied wines

In the following table are summarizes the wines employed in the two parts of this chapter.

Table 3.2.1. Summary of studied wines

Grape Areas	**Varieties**	**Yeasts and Inoculum**	**Grape treatments**
Area 1 and Area 2	Corvina and Corvinone	Yeasts 1-4 and Spontaneous fermentation	Fresh and withered

3.2.3. Standard enological analyses.

Standard enological analyses have been performed as reported in ***Chapter 1***.

3.2.4. SPE–GC-MS and SPME-GC-MS analysis.

SPE–GC-MS and SPME-GC-MS analysis of free volatile compounds have been performed as reported in ***Chapter 1***.

3.2.5. Sorting task

Sorting task has been performed as reported in ***Chapter 1***.

3.2.6. Statistical analysis

Principal Component Analysis (PCA), Kruskal Wallis (α=0.05) and Mann-Whitney test (α=0.05), one-way and two-way ANOVA of chemical data have been performed using XLSTAT 2017 (Addinsoft SARL, Paris, France).

3.3. Results and discussion

3.3.1. Wines obtained with fresh grapes

Enological parameters of musts at crush (**Appendix 3.3.1.1**) showed that glucose and fructose content varied to a minor extent between grape musts. Area 2 grapes showed slightly higher content than Area 1. Total acidity varied significantly across grape batches, and Corvina grapes showed lower total acidity values than Corvinone. pH was similar in all four musts, with values comprised between 3.1 and 3.18. Yeast assimilable nitrogen was higher in Corvinone grapes compared to Corvina, with smaller differences also occurring within the same variety. Enological parameters of wines are shown in **Appendix 3.3.1.2**, with the relevant ANOVA analysis presented in **Appendix 3.3.1.3**. Total acidity showed significant differences according to yeasts and the interaction between yeasts and areas in both Corvina and Corvinone wines. Wines fermented with Yeast 2 and Spontaneous fermentation showed higher total acidity. Only in Corvina wines there was an effect due to the grape origin, with Area 2 showing higher total acidity. pH depended for both varieties on grape area and area*yeast interaction but never on yeasts alone. Acetic acid content was, in all wines, lower than the legal limit as well as of its odor threshold (0.48 g/L). Only in Corvina wines yeast strain seemed to have an influence on acetic acid, with Yeast 2 and 3 showing the highest content, and Yeast 1 and 4 the lowest. Spontaneous fermentations showed intermediate levels of acetic acid. Ethanol was not affected by yeast but by grape origin, with Area 2 wines showing higher content, in agreement with the higher concentration of glucose and fructose of the grapes.

Quantified volatile compounds are shown in **Appendix 3.3.1.4-3.3.1.7**. In the case of Corvina wines (**Appendix 3.3.1.4** and **3.3.1.5**), thirty-six volatile compounds were found to significantly discriminate wines according to grape area of origin (**Appendix 3.3.1.8**) (α=0.05) including some C_6 alcohols, some esters and acids, as well as the majority of the terpenes, norisoprenoids and benzenoids analysed. Twenty-two volatile compounds showed statistically significant differences

(α=0.05) due to yeast strain/inoculation strategy, including the majority of alcohols, esters, acids, and only a few among terpenes, norisoprenoids, and benzenoids. Two-way ANOVA (Yeast*Area) indicated that twenty-four volatile compounds were significantly different, including in this case also some norisoprenoids that were not affected by either area or yeast alone, such as for example β-damascenone. In the case of Corvinone wines (**Appendix 3.3.1.6** and **3.3.1.7**), thirty volatile compounds were significantly different according to grape area (α=0.05, **Appendix 3.3.1.8**), including C_6 alcohols, several acetate esters, and the majority of terpenes, norisoprenoids and benzenoids. Twenty volatile compounds showed significant differences (α=0.05) linked to the yeast used, and these included alcohols, some esters but among acetate esters only ethyl acetate, fatty acids, and only a few among the terpenes, norisoprenoids, and benzenoids analysed. Two-way ANOVA indicated that twenty-six volatile compounds were significantly different according to the Yeast*Area interaction (**Appendix 3.3.1.8**).

In order to evaluate the influence of inoculation strategy, for each grape batch concentrations of individual volatile compounds in spontaneous fermentation samples were compared with the average concentrations obtained in all from inoculated fermentations by means of one-way ANOVA (**Appendix 3.3.1.9**). Approximately half of the measured compounds were at least in one case significantly affected by inoculation strategy. trans-3-Hexenol and 3-methylbutanoic acid were detected in significantly lower concentrations in all spontaneous fermentation, whereas ethyl acetate was more abundant in spontaneous fermentation for all batches. Other compounds or groups of compounds were occasionally affected depending on grape batch, so that for example in Corvinone from Area 2 several terpenes such as p-cymene and α-phellandrene occurred in significantly lower concentrations in spontaneous fermentation samples, whereas in Corvina from Area 2 slight but significant increases were observed for the norisoprenoids TDN, TPB, vitispirane.

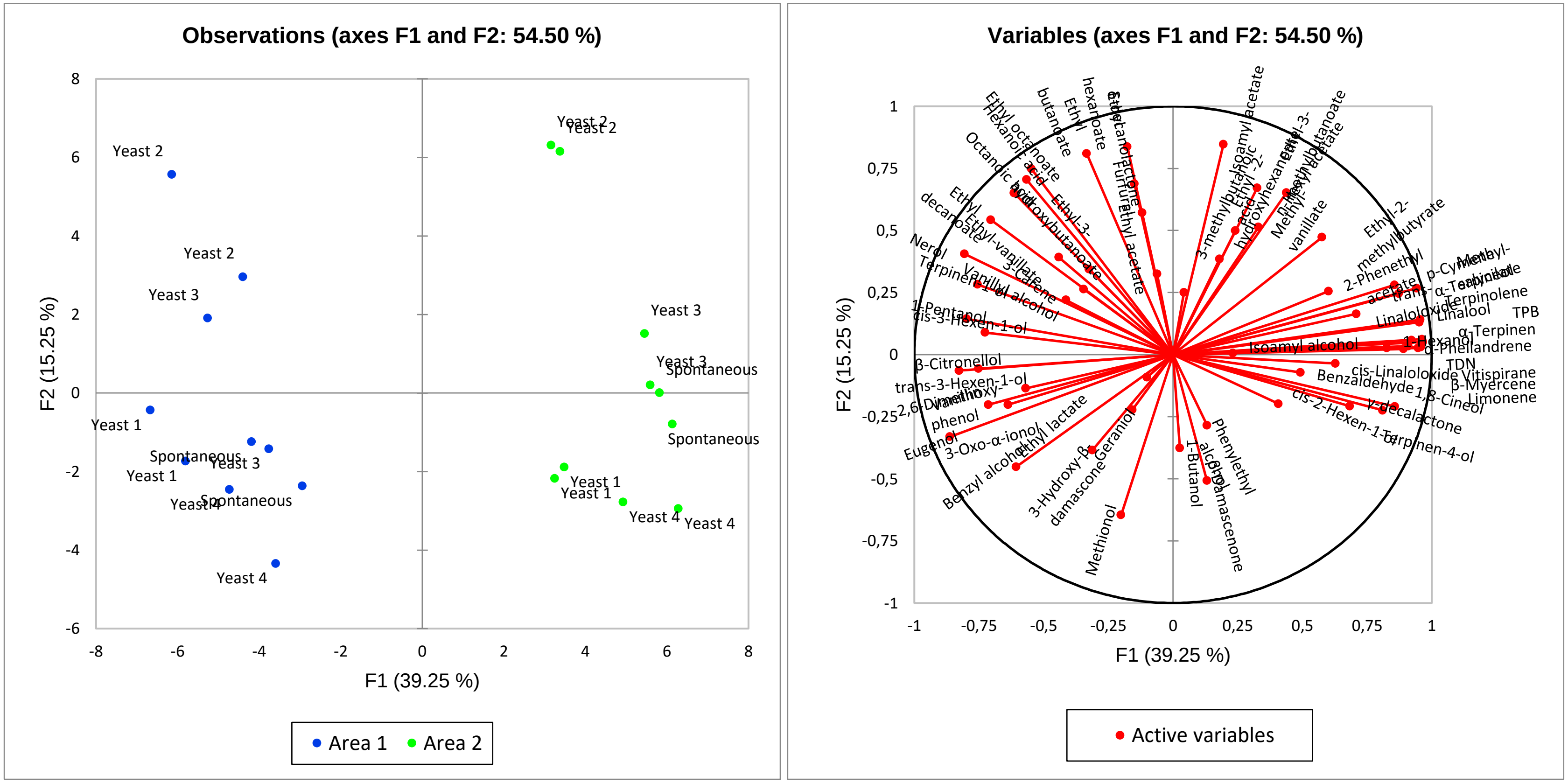
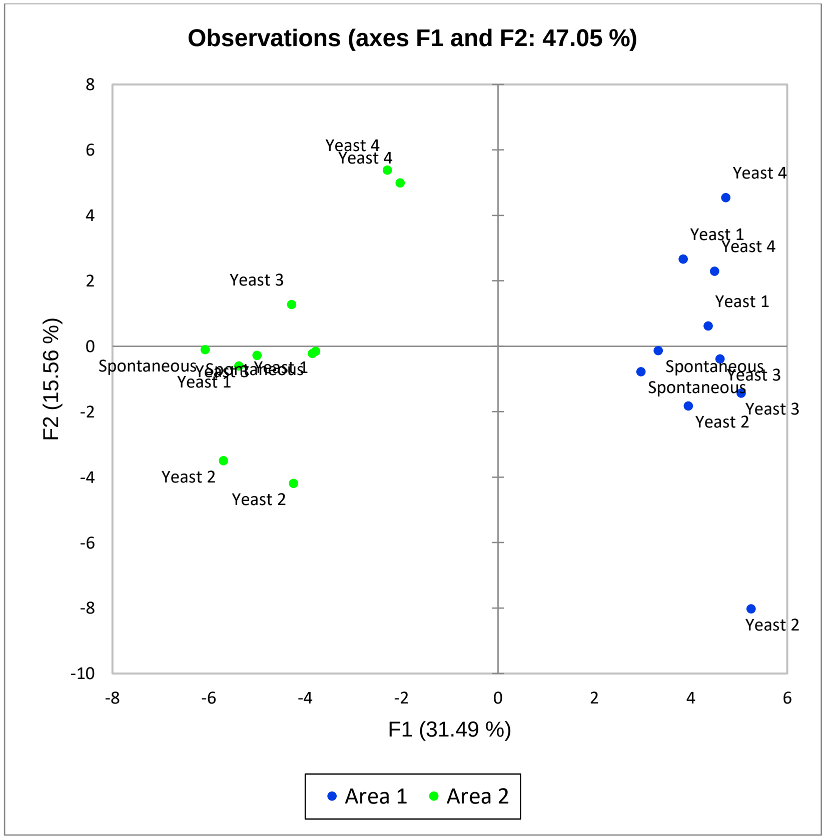


Figure 3.3.1.1. PCA of fresh Corvina wines



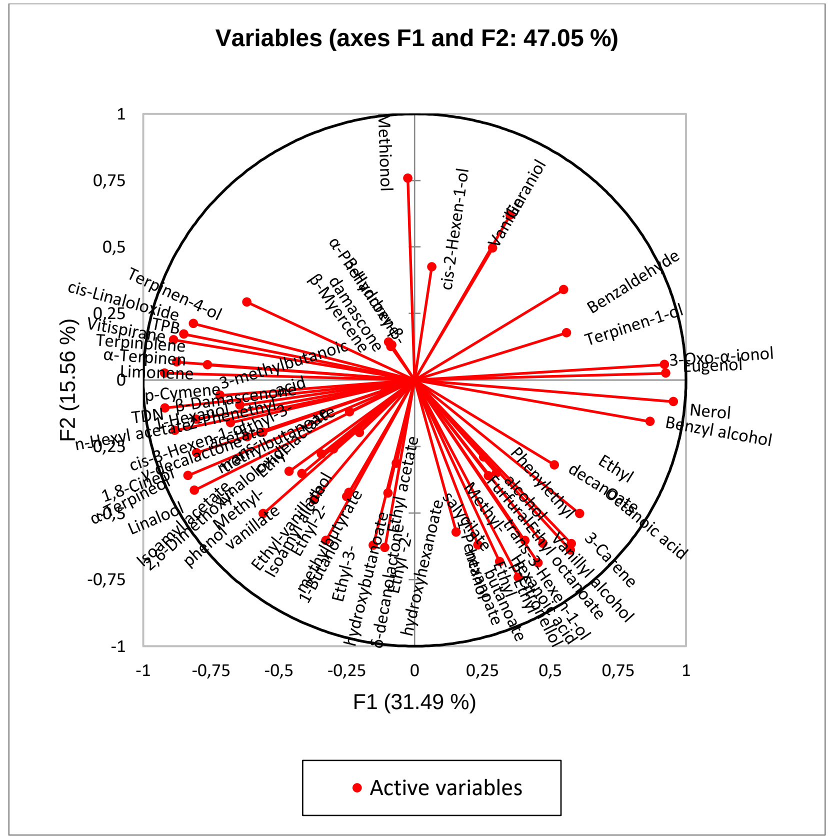


Figure 3.3.1.2. PCA of fresh Corvinone wines

For each grape variety, PCA analysis was carried out to generate a comprehensive overview of the datasets obtained. Respectively 55.4% and 47.05% of the total variance was explained with the first two principal components (**Figure 3.3.1.1** and **Figure 3.3.1.2**). In both the varieties PC1 was associated with grape origin and PC2 with yeast strain/inoculation. Results of One-Way ANOVA and Two-Ways ANOVA (**Appendix 3.3.1.8**) indicated that in Corvina wines 60% of analysed compounds was significantly affected by grape origin, whereas in Corvinone this value was 52%. Although the most of the analysed compounds were primarily associated with grape metabolism (e.g. C_6 alcohols, terpenes, norisoprenoids, benzenoids) and less deriving directly from fermentation (e.g. esters, higher alcohols, fatty acids), it has to be considered that occurrence, in wine, of certain grape-derived compounds such as monoterpene alcohols, β-damascenone, and benzenoids is also mediated by yeast activity (Ugliano, *et al.*, 2006) (Lloyd, *et al.*, 2011). Moreover, even in the case of certain compounds primarily related to yeast metabolism, such as for example the potent odorant isoamyl acetate, grape origin or area*yeast interaction were found to be more impactful than yeast strains alone. These observations indicate that the relationship between grape composition, yeast strain and wine volatile profile are rather complex and involve factors that probably only in part understood.

3.3.1.1 Influence of grape origin on wine volatile composition

Terpenes were clearly associated with area-driven differences. The importance of grape variety to wine terpenes content is well known (Mateo, *et al.*, 2000), and even for the same variety, terpenes profile can differ due to vineyard location (Slaghenaufi, *et al.*, 2019) (Wen, *et al.*, 2015) (Sabon, *et al.*, 2002), soil composition (Jackson, 2008), sunlight exposure (Bureau, *et al.*, 2000) and canopy management (Zoecklein, *et al.*, 2008). According to Wen *et al*. (2015) differences in free and bound terpenes in different origins grapes are related to key genes involved in terpene biosynthesis, markedly up-regulated. In particular, the expression of 1-hydroxy-2-methyl-2-butenyl 4-diphosphate reductase can promote the flow of isopentenyl diphosphate (IPP) into the terpene synthetic pathway. In the case of Corvina, the average total terpenes content of wines from Area 2 was 29% higher than wines from Area 1, whereas Area 2 Corvinone wines showed average terpenes content 10% higher than Area 1, in particular a 1.5-fold higher content of linalool. Other authors have reported terpene variations in association with grape origin, although this was observed across relatively large geographical areas, in some cases covering different latitudes

(Slaghenaufi, *et al*., 2019) (Robinson, *et al*., 2011) (Antalick, *et al*., 2015) (Celik, *et al*., 2015). In our case, the two areas are about 15 km apart, virtually on the same latitude and the vineyards have similar altitude (approximately 350 m a.s.l). One aspect that is worth mentioning though is that grapes from Area 2 were harvested at slightly higher sugar content (4 g/L and 15 g/L of sugar content for Corvina and Corvinone respectively), and that this area is much closer to the Garda Lake.

Norisoprenoids discriminated wines based on area of grape origin, again with wines from Area 2 showing higher concentrations. During our study, β-damascenone did not show significant difference according to yeast alone, although a significant degree of area*yeast was observed. Among other norisprenoids, vitispirane and TDN were characterized by camphoraceous and kerosene odors. In our study, both vitispirane and TDN were detected in higher concentrations in wines from Area 2, in particoular in Corvinone wines. TDN concentrations in certain cases approached the detection threshold of 2 µg/L reported by Sacks, *et al*., (2012). Also in this case significant area*yeast effects were observed.

Benzenoids compounds were also found to discriminate to some extent the wines based on area of grape origin, in particular for benzyl alcohol, vanillin, eugenol, 2,6-dimethoxyphenol. Variations in benzenoids across Corvina wines from grapes of different vineyards have been recently reported (Slaghenaufi, *et al*., 2019) including an effect of vineyard location on the most abundant benzenoids compounds measures herein, namely ethyl vanillate. Such variability was however not observed in the present study.

Finally, C_6 alcohols were also significantly affected by area, in particular in Corvina wines. Formation of these compounds, potentially contributing wine herbaceous odors, is associated with the steps of grape crushing (Baumes, 2009). C_6 compounds in wines can be associated with grape variety, maturity and technological variables, in agreement with the findings of the present study (Jackson, 2008).

3.3.1.2. Influence of yeast strain and inoculum on wine volatile composition

Although strictly speaking for each variety four sets of fermentations were carried out by means of inoculation and one by spontaneous fermentation, the latter was initially considered, for the sake of data processing, as an additional strain treatment. We have not carried out a specific characterization of the yeast strain(s) that contributed the spontaneous fermentation, and a contribution of some of the other yeast strains used cannot be excluded. However spontaneous fermentations differed in all cases from inoculated ones in terms of fermentation kinetics, which were always slower, in agreement with the observations of Medina *et al*. (2013). Volatile analyses also indicated a different metabolic fingerprint for this modality, supporting the hypothesis that the microbial background of the spontaneous fermentation treatment was different. As previously mentioned, yeast strain was found to have a less prominent influence on wine aroma composition compared to area of grape origin. This can be clearly seen in **Figures 3.3.1** and **3.3.2**, where discrimination of wines based on yeast strain was associated with PC2, accounting for less than 16% of the total variance. Nevertheless, some strain-related patterns were observed, for example yeast 2 (AWRI 796) systematically produced higher concentrations of isoamyl acetate, hexyl acetate, and ethyl fatty acid esters, which appears to be in agreement with previous observations concerning increased aroma formation capabilities of this strain (Borneman, *et al*., 2011).

Likewise, for the *Saccharomyces cerevisiae x Saccharomyces kudriavzevi* hybrid (yeast 1), higher levels of 1-butanol but not of 2-butanol were always, potentially reflecting specific metabolic traits for butanol isomers pathways (Generoso, *et al*., 2015) as well as possible differences in nitrogen utilization patterns in *S. Kudriavzevii* compared to *S. cerevisiae* (Stribny, *et al*., 2015).

Among the compounds primarily associated with yeast direct biosynthesis, namely esters, alcohols and acids, esters are largely responsible for wine fruity attributes, and therefore they play an important role in the sensory composition of young red wines (Antalick, *et al*., 2014). Several authors have reported a major influence of yeast strain on wine ester profile (Reviewed in Ugliano and Heschke, 2009) related to different levels of expression of acetyl transferases for acetate esters (Lilly, *et al*., 2000) and esterification of activated fatty acids (acyl-CoA) during lipid biosynthesis for ethyl esters (Suomalainen, 1981). In most of the published studies, the relationship between esters and yeast strain was studied by inoculating a single must with different yeasts. However, when different combinations of yeast and musts are studied, as in the case of the present work, the situation appears more complex. This can be seen in **Figure 3.3.1.3**, showing that only for some classes of esters a significant influence of yeast alone existed. In particular, ethyl esters of both linear and branched fatty acids were in nearly all cases affected by yeast strain and not by area, whereas acetate esters showed a mixed trend, with only ethyl acetate being significantly affected by yeast in all cases. It is worth mentioning that this did not imply that in no case compounds such as the potent odorant isoamyl acetate were significantly influenced by yeast. In fact from the data of wine sets from individual grape batches it can be seen that yeast-induced variations in isoamyl acetate concentrations were up to five folds in the case of Corvina (for which a significant influence of yeast alone was observed), whereas in the case of Corvinone they were around two folds. At the same time, within the same variety, variations due to area of grape origin were generally of a factor two, so that for acetate esters yeast*area was more impactful than yeast alone. Altogether these observations indicate that the extent at which yeast strain can impact ester formation during fermentation is strictly modulated by grape composition, and in certain fermentation batches the effect of yeast can be relatively small, in particular for acetate esters, as seen Area 1 Corvinone.

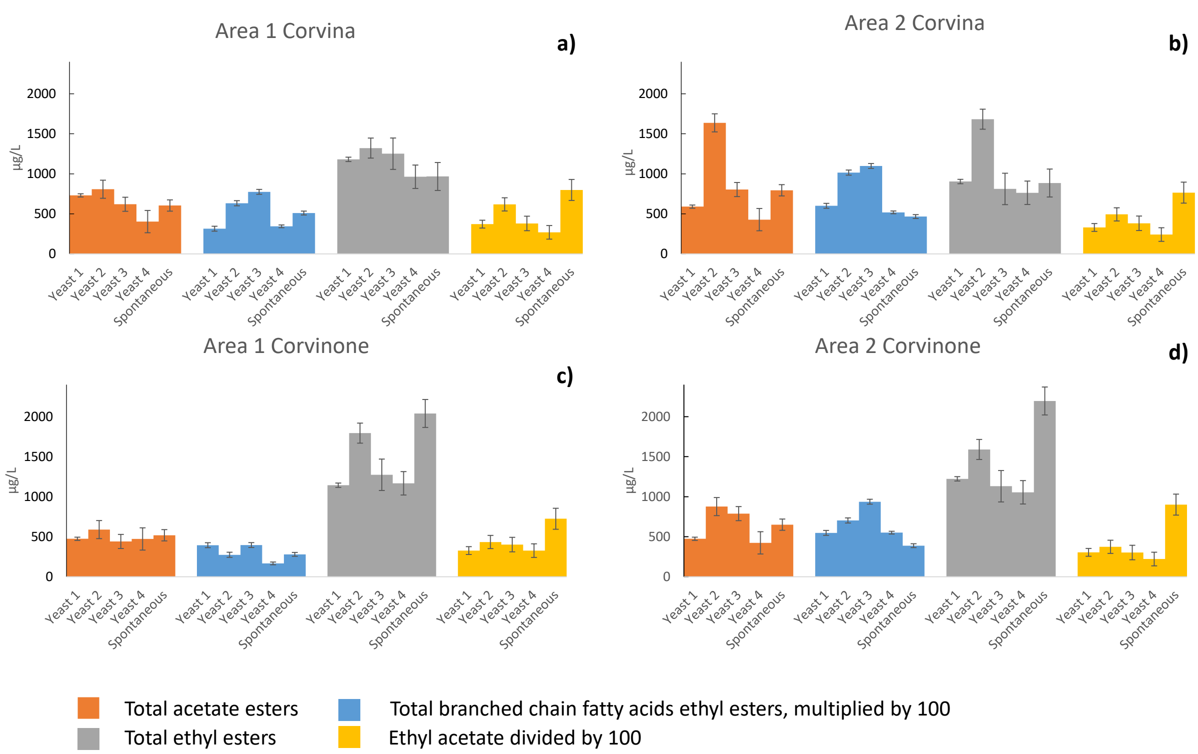


Figure 3.3.1.3. Total acetate esters, total branched-chain fatty acid ethyl ester, total ethyl fatty acids esters and ethyl acetate content (divided by 100) in (a) Area 1 Corvina wines, (b) Area 2 Corvina wines, (c) Area 1 Corvinone wines and (d) Area 2 Corvinone wine

In both Corvina and Corvinone, spontaneous fermentation wines show the highest concentration of ethyl acetate, for both area 1 and area 2 grapes. Its concentration reaches a content 4-fold higher than wines of the same cultivar, grown in the same area fermented with commercial yeasts. Ethyl acetate was the most abundant ester in wine and at high concentrations can be responsible for acetic notes (Plata, *et al*., 2003).

Contrary to esters, alcohols, showed significant differences due to yeasts in both Corvina and Corvinone wines with 83% of total alcohol compounds significantly affected by yeast in varieties. Compounds such as isoamyl and phenylethyl alcohols as well as methionol are produced by yeast metabolism from either catabolism of sugars or amino acids decarboxylation and reduction coupled to oxidation of NADH via Ehrlich pathway. With regard to the well-established influence of YAN on higher alcohol metabolism (Ugliano, *et al*., 2009) no relationship was observed in this chapter, although it has to be mentioned that differences in grape YAN levels were relatively small.

Certain compounds primarily associated with grape were also affected by yeast strain. Among these, geraniol, 3-hydroxy-β-damascone and vanillin were for the most part affected by yeast and not by area. *Saccharomyces cerevisiae* is able to synthesize terpenes such as geraniol (Ugliano, *et al*., 2009) (Gramatica, *et al*., 1982), but the contribution of this pathway is expected to be minor compared to release from glycosidic precursors and/or bio transformation of other terpene geraniol (Ugliano, *et al*., 2009). Yeast 4 wines systematically in both varieties showed lower content, up to 1.7-fold less. Since the intensity of terpene biotransformation depends on the employed yeast strain (Dugelay, *et al*., 1992) different β-citronellol and geraniol occurrence could be due to peculiar balance of hydrolytic and reductive activities. Vanillin derivatives can be produced by yeast as by-products of ferulic acid metabolism (Huang, *et al*., 1993) and some of these (for example vanillic acid) could be esterified by yeast or through acid catalysed reactions. An association between fermentation and increase in ethyl vanillate concentration has been recently reported in Corvina (Slaghenaufi, *et al*., 2019) which could explain the observation of a significant influence of yeast.

With regard to the influence of inoculation strategy, results indicated that ethyl acetate was systematically produced in significantly higher concentrations in spontaneous fermentations (**Figure 3.3.1.3**, **Appendix 3.3.1.9**). This is in agreement with the data of Plata *et al.* (2003) where indigenous yeasts show high production rates of ethyl acetate during fermentation.

3.3.1.3 Wine sensory evaluation

In agreement with the results of chemical analyses, the sorting task aimed to identifying patterns of olfactive similarities across samples indicated that area of grape origin played a primary role in determining wine aroma characteristics. Results of the sorting task obtained by means of HCA are shown in **Figure 3.3.1.4**. In general, replicate wines were projected in the same groups obtained by HCA, suggesting that fermentation replicates were similarly perceived by the panellists. In the case of Corvina (**Figure 3.3.1.4**), samples were clustered in three groups. One larger group consisted of seven wines, five of which were obtained from grapes of Area 1. A second group consisted of five wines all associated with both areas, and finally a third group of eight wines, six of which were associated with Area 2. In terms of yeast strain/inoculation strategy, fermentation replicates were generally sorted in the same group, the only exception being yeast 2 from Area 2 that spanned across second and third group. Interestingly, all spontaneous fermentations were sorted in the third group, regardless of grape origin. Also, in the case of Corvinone (**Figure 3.3.1.4**) three groups were obtained, with the first largest group consisting of ten wines, nine of which were associated with Area 1. The second group consisted of four wines, all from Area 2, fermented with yeast 1 and 4. Finally, a third group of six wines was obtained, five of which were associated with Area 2. Also, in this case fermentation replicates were for the most correctly allocated in the same group, the only exception being yeast 2. Samples obtained by means of spontaneous fermentations were separated depending on area. The fact that grape origin played a major role was particularly clear in the case of Corvinone (**Figure 3.3.1.4**), where the two main clusters indicated by tasters were clearly associated with the area variable. For Area 2 two further clusters were observed, with one consisting of the samples obtained by means of yeasts 2 and 3. Altogether, these results indicated that odor similarities perceived across samples were primarily associated with area, with yeasts 2 and 3 exhibiting further elements of odor similarity within Area 2. The case of Corvina was different and in general sorting of the samples based on odor similarity was less clearly attributable to either area or yeast. Nevertheless, a certain influence of yeast strain could be observed on the formed clusters, with yeast 2 samples were all grouped in one cluster regardless of area. Likewise, all samples from spontaneous fermentation were grouped in another cluster, with no distinction due to grape area.

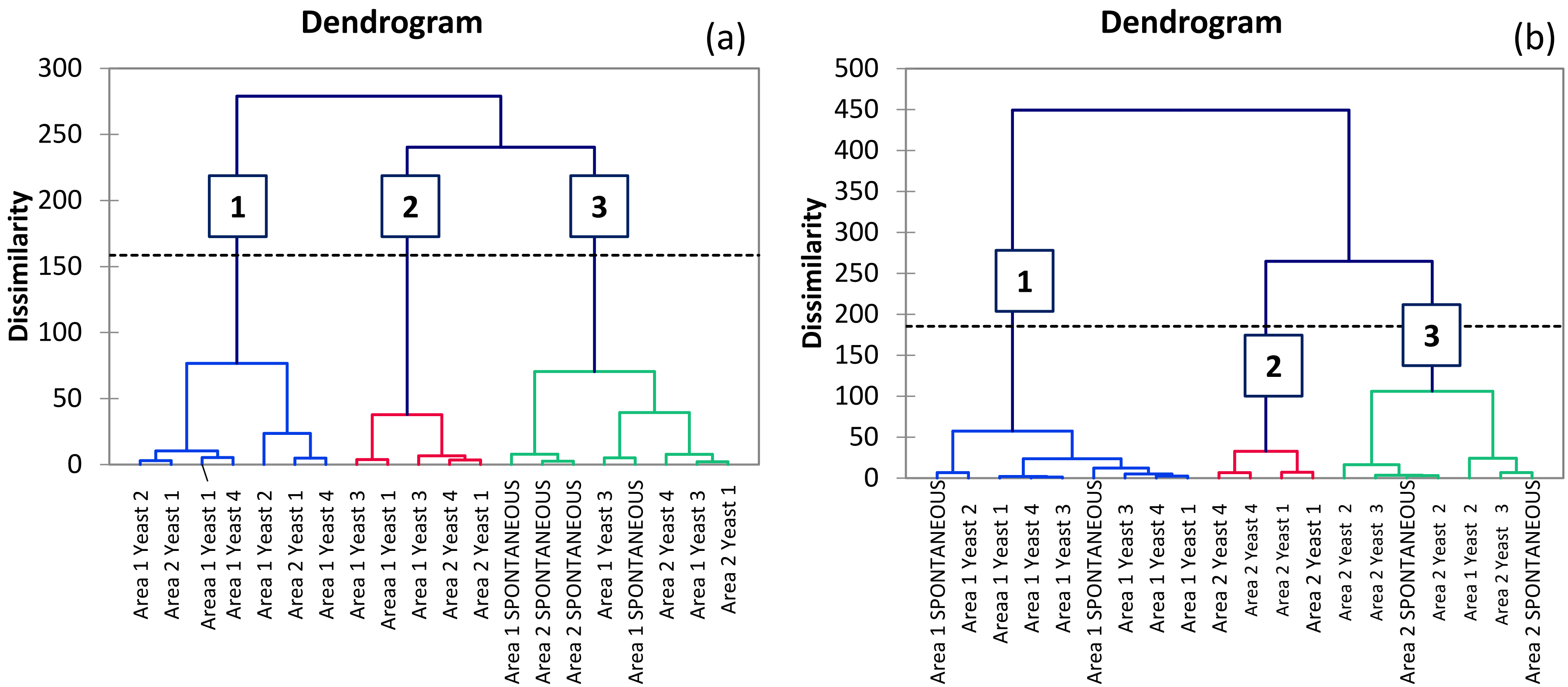


Figure 3.3.1.4. HCA of (a) Corvina and (b) Corvinone sorting tasks data

This seems in good agreement with aroma chemical analyses, as yeast 2 was characterized by increased production of ethyl fatty acids esters as well as acetates, whereas samples from spontaneous fermentations exhibited higher concentrations of ethyl acetate The fact that such influence of yeast strain and inoculum strategies was more clearly detected in Corvina samples might depend on the fact that ester biosynthesis appeared to be generally more intense in Corvina fermentations, so that the 'estery' character of yeast 2 was more intensely expressed. For each variety, classes of compounds discriminating clusters to a statistically significant degree were assessed by Mann Withney test (**Appendix 3.3.1.10**). The classes reported in **Appendix 3.3.1.5-3.3.1.8** were used, except for terpenes that were divided into linear terpenes (linalool, β-citronellol, geraniol, limonene, nerol) and cyclic terpenes (trans-linalooloxide, cis-linalooloxide, α-terpineol, 3-carene, α-phellandrene, α-terpinen, 1-8-cineole, p-cymene, terpinolene, terpinen-1-ol, terpinen-4-ol), benzenoids which were separated miscellaneous group and ethyl acetate which was studied separately. The results of this are shown in **Figures 3.3.5** and **3.3.6**.

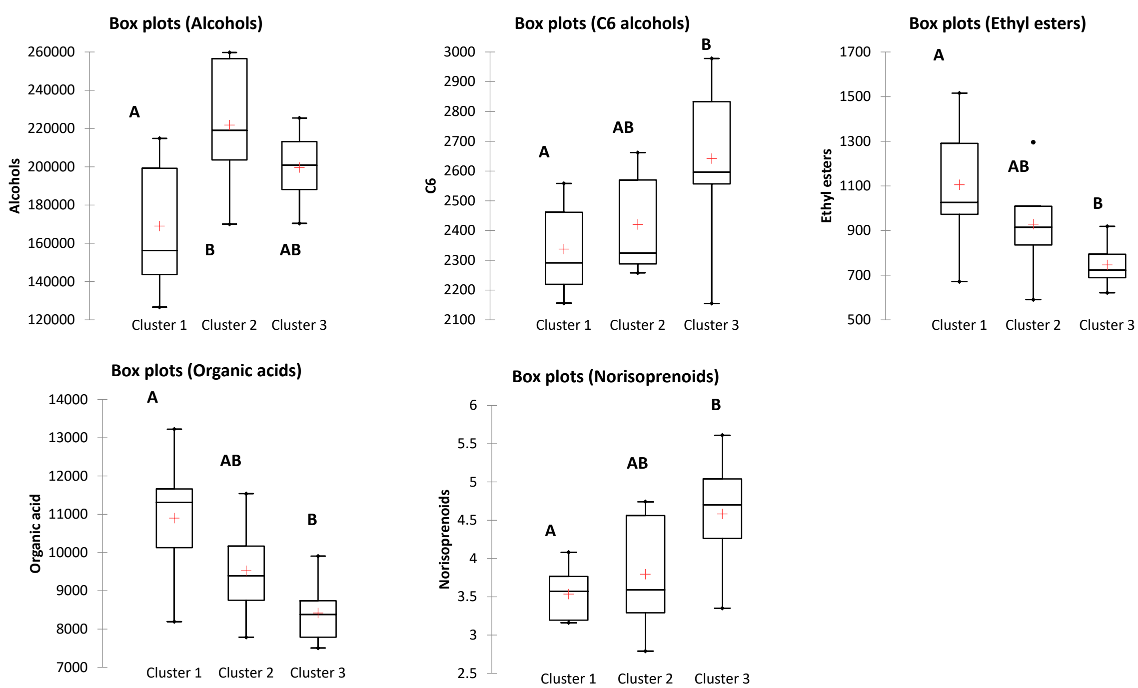


Figure 3.3.1.5. Box Plot of chemical classes with significant differences (capital letters) according to Mann-Withney test (α=0.05) of Corvina HCA clusters.

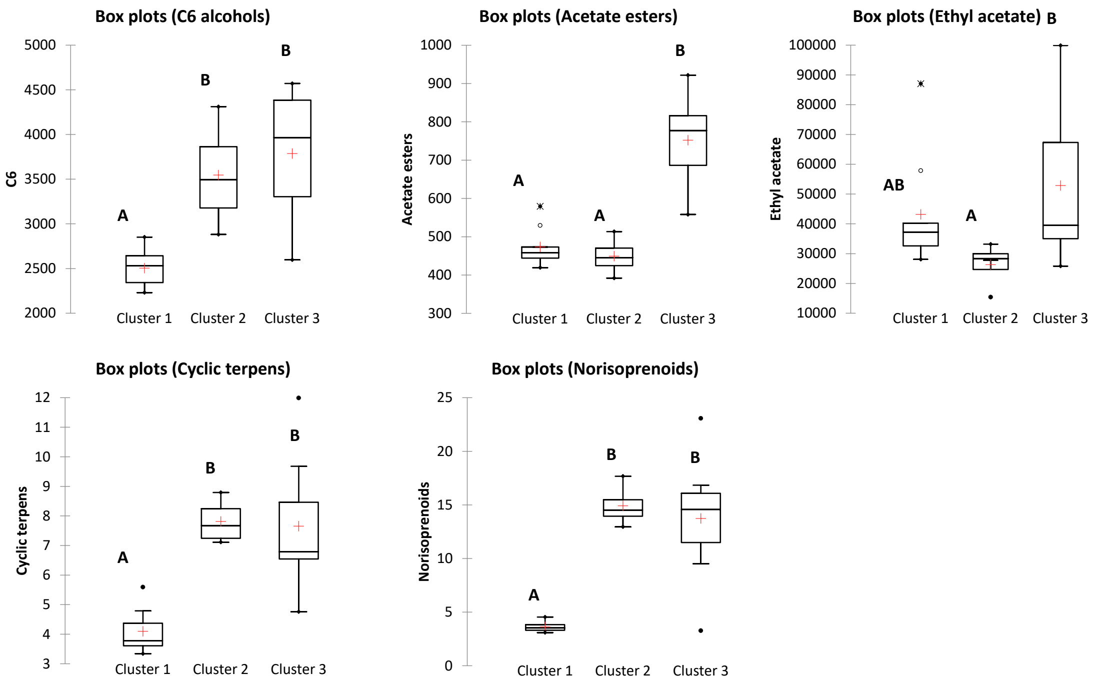


Figure 3.3.1.6. Box Plot of chemical classes with significant differences (capital letters) according to Mann-Withney test (α=0.05) of Corvinone HCA clusters.

Corvina cluster 1 (**Figure 3.3.1.5**) was characterized by a significantly higher content of fruity esters than cluster 3, in particular ethyl butanoate, octanoate and decanoate, and fatty acids, such as hexanoic and octanoic acids. Cluster 3, instead, show significantly higher content than cluster 1 of C_6 alcohols and norisoprenoids. In all these cases cluster 2, which consisted of wines belonging to both grape areas and fermented with yeasts 1, 3 and 4, showed intermediate content, not different from clusters 1 and 3. However, cluster 2 also showed higher content of alcohols, which can suppress fruity attributes (Ferreira, et, al., 2016). In Corvinone wines (**Figure 3.3.1.6**) cluster 1 showed a significantly lower content of C_6 alcohols, cyclic terpenes and norisoprenoids compared with cluster 2 and 3. As for cluster 2 and cluster 3, they were mainly distinguished by the total content of acetate esters, which was significantly higher in cluster 3. This was associated to different yeast or inoculum, since cluster 3 is formed by Yeast 2, 3 and spontaneous fermentation and cluster 2 by Yeast 1 and 4. Ethyl acetate also differentiated these the two clusters, specifically due to the presence of spontaneous fermentations in cluster 3, which was indeed associated with increased content of ethyl acetate.

3.3.2. Wines obtained with withered grapes

Enological parameters of withered grapes musts at crush are shown in **Appendix 3.3.2.1**. Area 2 wines showed higher glucose+fructose than Area 1. YAN content in Corvina was very similar between the two Areas, while Corvinone Area 1 showed 45 mg/L more than Area 2. Enological parameters of wines and their ANOVA analysis are shown in **Appendix 3.3.2.2** and **3.3.2.3**. pH and total acidity were primarily affected by grape origins, and only in Corvinone also by yeasts and their interaction with area. Acetic acid was mainly influenced by yeast in both the varieties and spontaneous fermentation showed much higher content then the other treatments, above 0.8 g/L. Since acetic acid in some wines is already perceived at 0.48 g/L, its sensory involvement has been considered. Area 1 wines, in both varieties, in agreement with different glucose+fructose content of musts showed higher ethanol levels. The content of volatile compounds, including esters, alcohols, fatty acids, terpenoids, norisoprenoids, and benzenoids, in each studied wine were reported in **Appendix 3.3.2.4-3.3.2.7**. In Corvina wines twenty-eight volatile compounds were found to be significantly affected by grape area of origin (**Appendix 3.3.2.8**), including some fermentative compounds, as well as the majority of the terpenes, norisoprenoids, benzenoids and C_6 alcohols analysed. Nineteen volatile compounds, mainly of fermentative origin, showed statistically significant differences due to yeast strain/inoculation strategy. In the case of Corvinone wines, thirty-one compounds were significantly affected by grape area of origin, while nineteen by employed yeast. To evaluate the influence of inoculation strategy, spontaneous fermentation wines were compared with the average concentrations of all inoculated fermentations (**Appendix 3.3.2.9**). In Corvina and Corvinone wines from Area 1, respectively twenty-eight and twenty-one compounds were found significantly different, while in Area 2 fourteen and seventeen. For each grape variety PCA analysis was performed. Respectively 49.45% and 50.58% of the total variance was explained with the first two principal components (**Figure 3.3.2.1** and **Figure 3.3.2.2**) with the PC1 associated with grape origin and PC2 with yeast strain/inoculation. Spontaneous fermentations were characterized by more negative values on PC2 than inoculations, in both varieties, in both Areas.

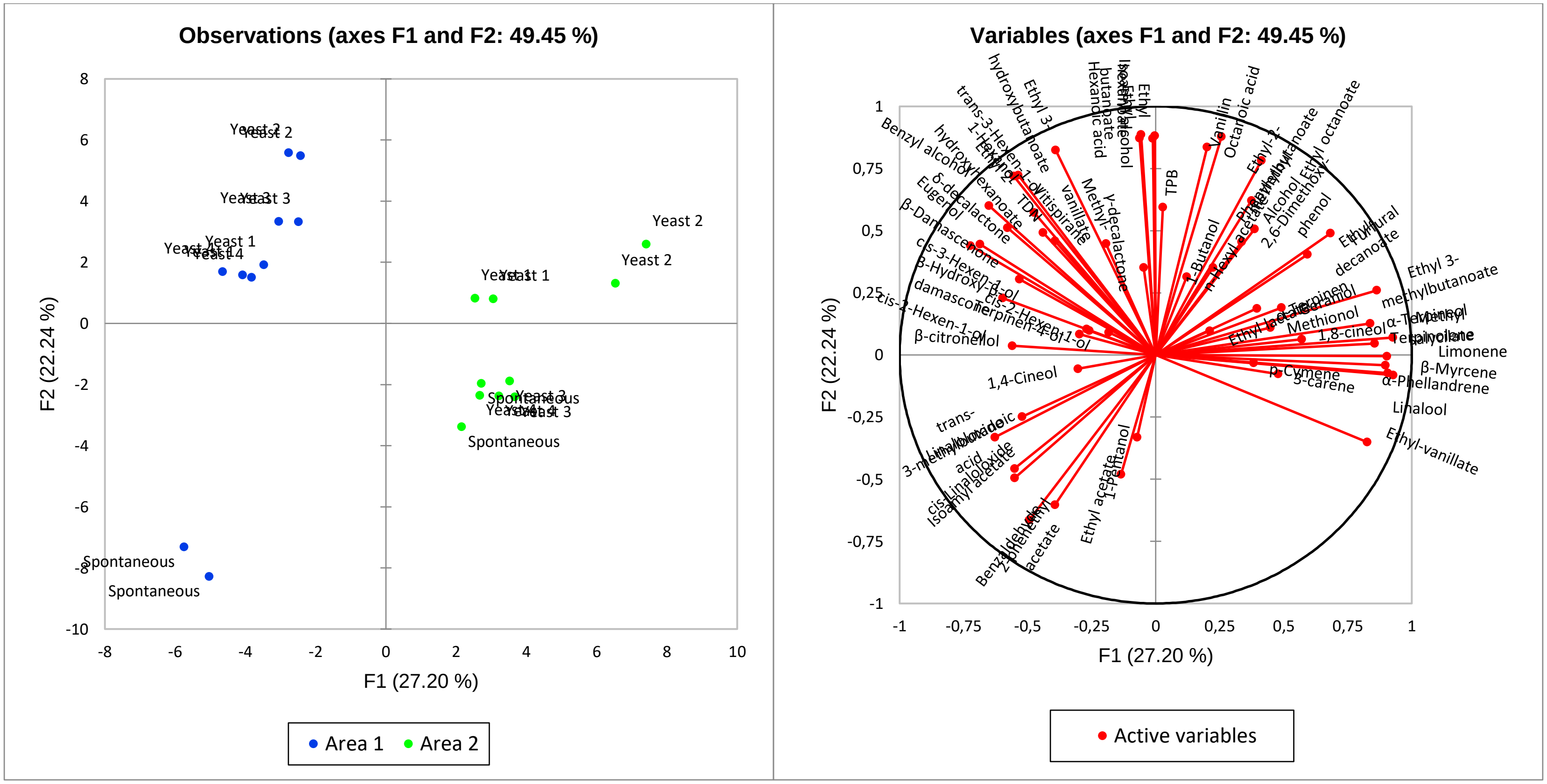


Figure 3.3.2.1. PCA of withered grapes Corvina wines

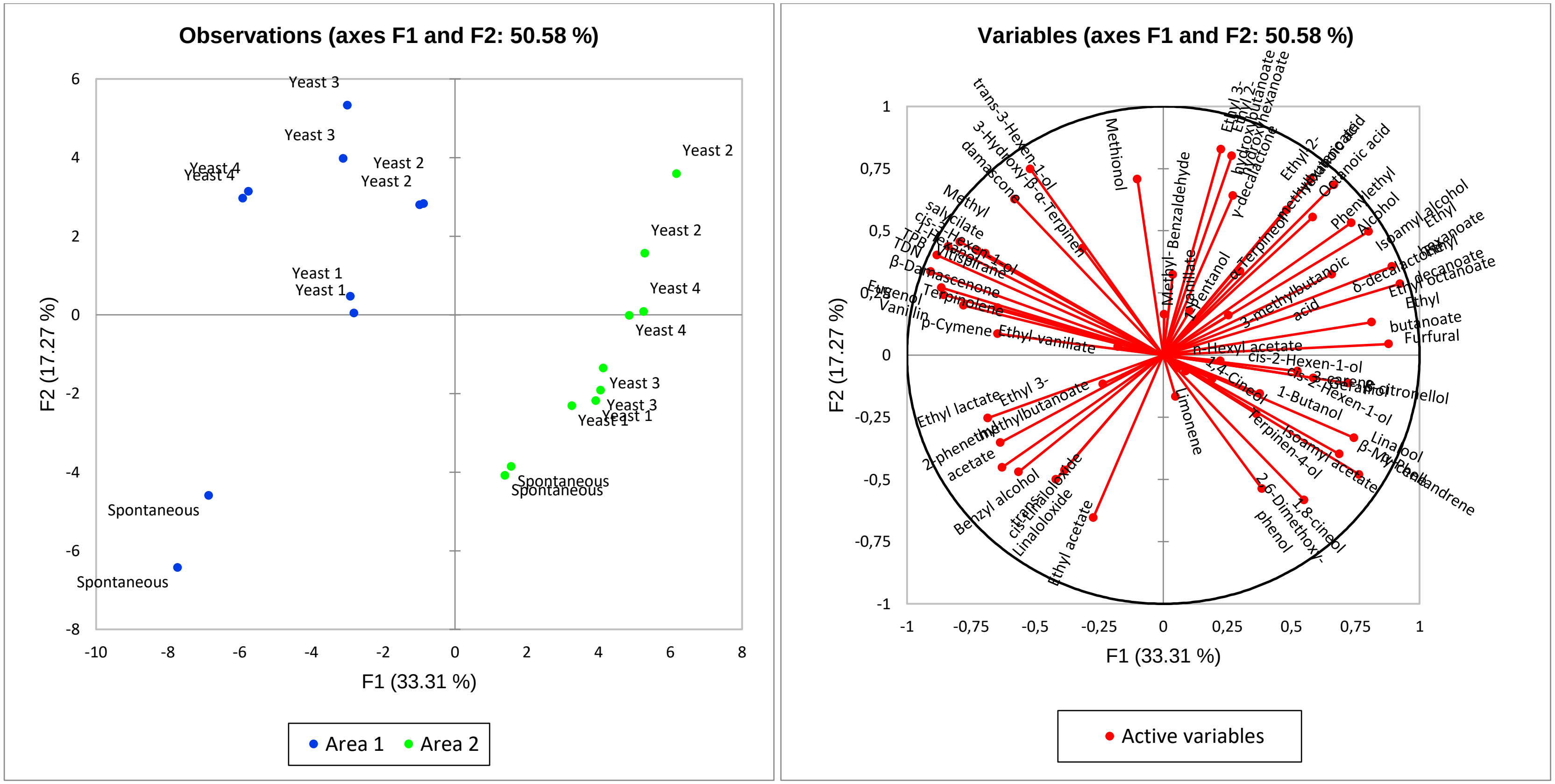


Figure 3.3.2.2. PCA of withered grapes Corvinone wines

3.3.2.1. Influence of grape origin on wine volatile composition

In both varieties about 50% of analysed compounds were significantly affected by grape origin (**Appendix 3.3.2.8).** Terpenes and norisoprenoids were associated with grape origin, with Area 2 showing higher terpenes levels and Area 1 higher norisoprenoids. Area 2 wines were characterized by higher content of linalool and α-phellandrene. Corvina Area 2 wines showed also higher β-citronellol content and Corvinone higher α-terpineol. All individual norisoprenoids, β-damascenone and vitispirane in particular, showed significant higher content in Area 1 wines except TPB. All C_6 compounds a part cis-2-hexen-1-ol showed significant higher content in Area 1 wines. Area 1 wines showed also slightly higher average total benzenoids content. Finally, Area 2 Corvinone showed significant higher content of the main ethyl esters (e.g., ethyl butanoate, hexanoate, octanoate and decanoate). Corvina Area 1 wines showed 1.4-fold higher isoamyl acetate content. Corvina grapes, however, did not show a different YAN content. In the previous chapter we found, as also reported by literature (Robinson, *et al*., 2014), that isoamyl acetate was regulate by grapes YAN content but the isoamyl acetate/YAN yield could also be affected by other factors that could be at the basis of the differences found in this chapter.

3.3.2.2. Influence of yeast strain and inoculum on wine volatile composition

As for fresh grapes wines, fermentations were carried out by means of inoculation with the same four commercial yeasts employed in the previous part of the study and one by spontaneous fermentation. Yeast strain was found be less influent compared to grape origin. In this case, some strain-related patterns were observed on the PCA plot but considering wines of the same variety as a single batch only 55% of Corvina and 64% of Corvinone fermentative compounds were significatively affected by yeasts (**Appendix 3.3.2.8**). Considering individually the different combinations of variety-area, almost all fermentative compounds were in nearly all cases affected by yeast strain (α=0.05) (**Appendix 3.3.2.10**). 95% of fermentative compound were significatively affected by yeast in Area 1 Corvina, 60% in Area 2 Corvina and 86% in Area 1 and 2 Corvinone. This situation can be seen in **Figure 3.3.2.3**, where concerning total average content of different esters classes, a part from acetate esters in Corvina wines, all classes were affected by yest strains. The impact of yeast strains on ester was therefore strongly modulated by grape composition. Yeast 2 systematically produced higher content of acetate and ethyl esters, while yeast 4 produced low levels of ethyl esters. In both Corvina and Corvinone, spontaneous fermentation wines showed the highest concentration of ethyl acetate and ethyl lactate, for both grape areas. Ethyl acetate concentration reached a content 3.6-fold higher compared with wines of the same Cultivar-Area fermented with commercial yeasts.

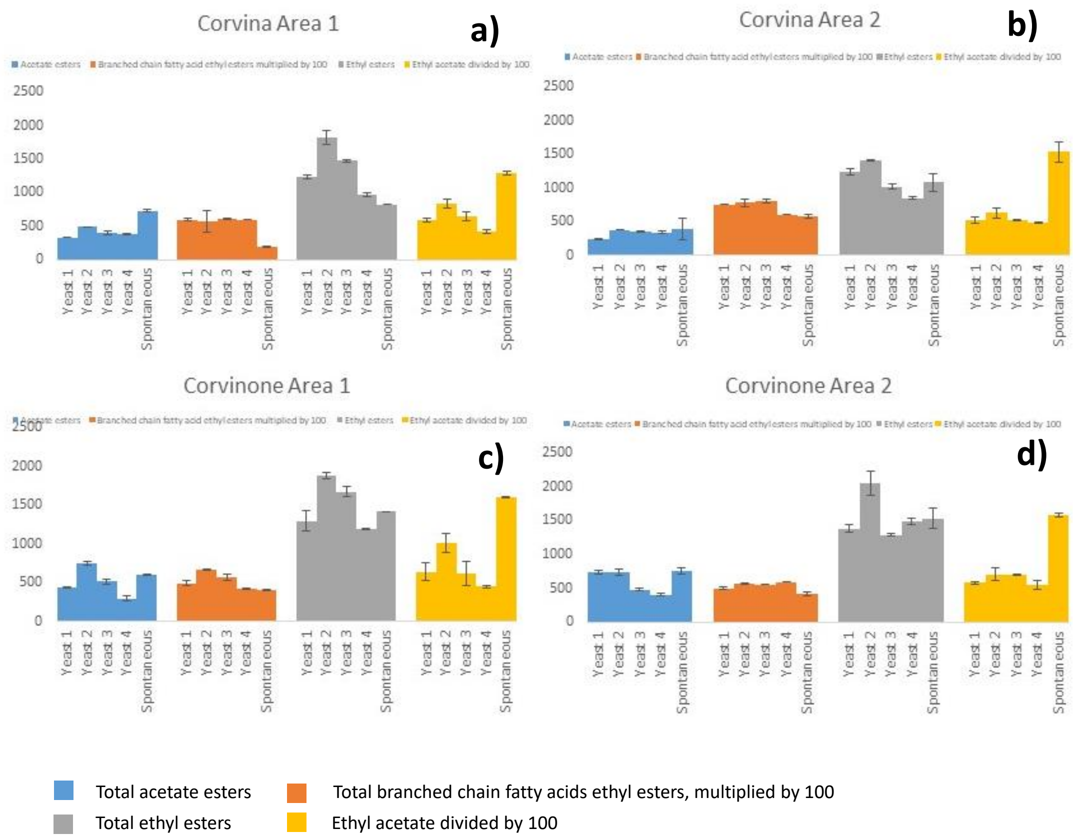


Figure 3.3.2.3. Total acetate esters, total branched-chain fatty acid ethyl ester, total ethyl fatty acids esters and ethyl acetate content (divided by 100) in (a) Area 1 Corvina (b) Area 2 Corvina, (c) Area 1 Corvinone and (d) Area 2 Corvinone withered grapes wines.

3.3.2.3. Wine sensory evaluation

In agreement with multivariate analyses, sorting tasks indicated that grape area of origin played a major role. Results of the sensory analysis obtained by HCA of sorting task data are shown in **Figure 3.3.2.4**. Replicates wines were projected in the same cluster, meaning that the panel was reproducible and the wine replicates were similar. In the case of Corvina, wines were clustered in three groups. Cluster 1 consisted of all inoculated wines from Area 1. Cluster 2 consisted of all the spontaneous fermentations regardless of grape origin. Finally, all the inoculated wines from Area

2 were grouped in cluster 3. Also, in the case of Corvinone three clusters were obtained. Cluster 1 consisted, again, of all inoculated wines from Area 1. The second cluster consisted of four wines, all from Area 2, fermented with yeast 1 and 4. Finally, cluster 3 consisted of the remaining Area 2 wines and all the spontaneous fermentations.

In both varieties area of grape origin had a major impact than yeast strain. It is worth mentioning that in both the variety spontaneous fermentation were clustered together regardless of grape area of origin. This was particularly evident in Corvina where spontaneous fermentations formed a cluster on their own.

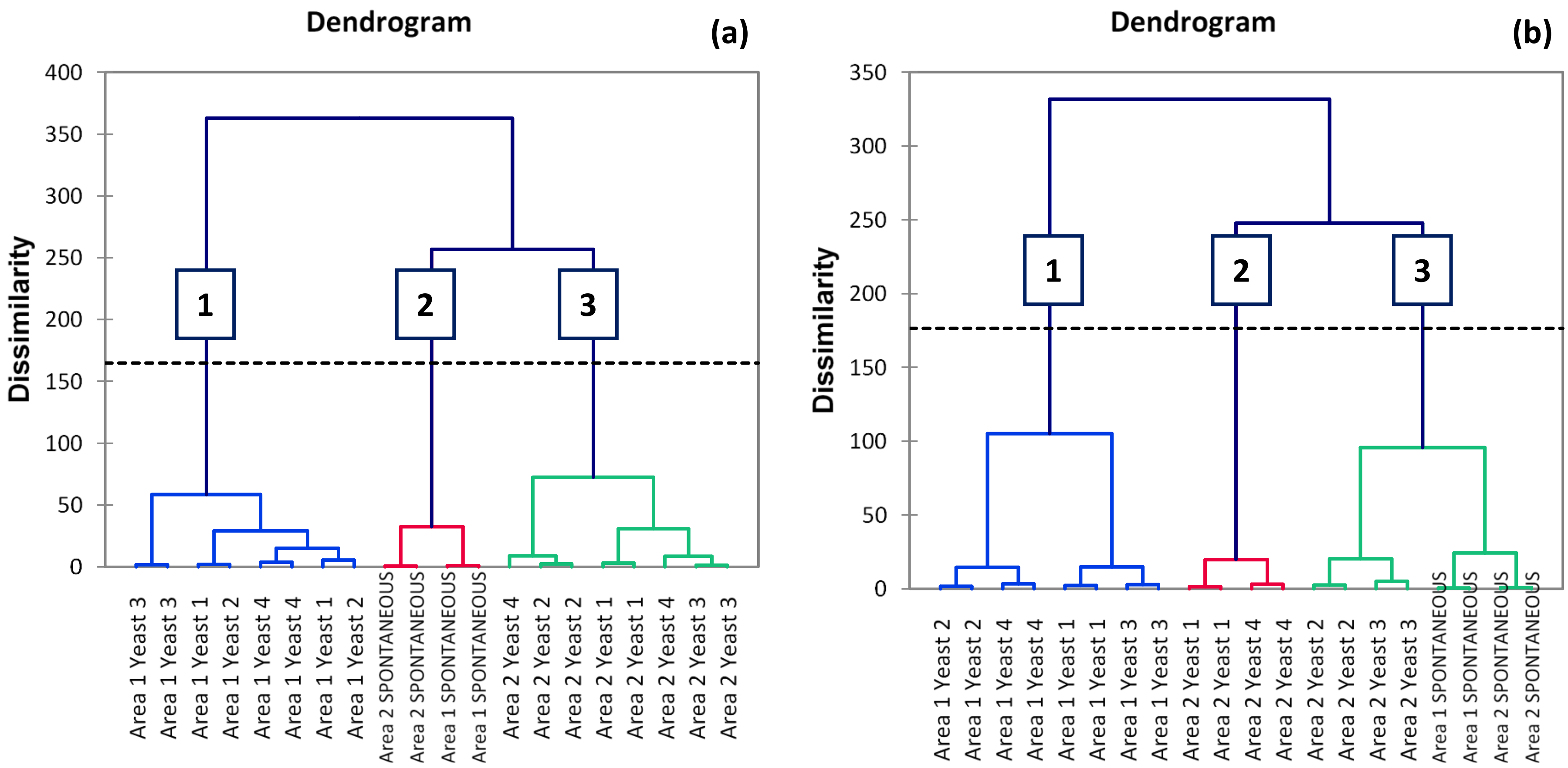


Figure 3.3.2.4. HCA of a) Corvina and b) Corvinone withered grapes wines sorting task data

Since in Corvina cluster 1 and 3 were respectively the wines of Area 1 and 2, the classes of compounds distinguishing them were the same that distinguished the two Areas (**Figure 3.3.2.5**) (significantly different classes of compounds are listed in the **Appendix 3.3.2.11**). Cluster 1 was distinguished from cluster 3 by higher content of alcohols, C_6 alcohols, acetate esters, norisoprenoids, benzenoids. Cluster 3 instead showed higher branched chain ethyl esters and cyclic terpenes. Cluster 2 (spontaneous fermentations) in addiction to high content of ethyl acetate was also characterized by high concentrations of acetic esters in general. Concerning Corvinone cluster 1 formed by all Area 1 wines fermented with commercial yeast showed higher C_6 alcohols and norisoprenoids (**Figure 3.3.2.6**). Cluster 2 and 3 (Area 2 wines) showed higher terpenes. Cluster 3 being formed by all the spontaneous fermentation showed higher ethyl acetate content.

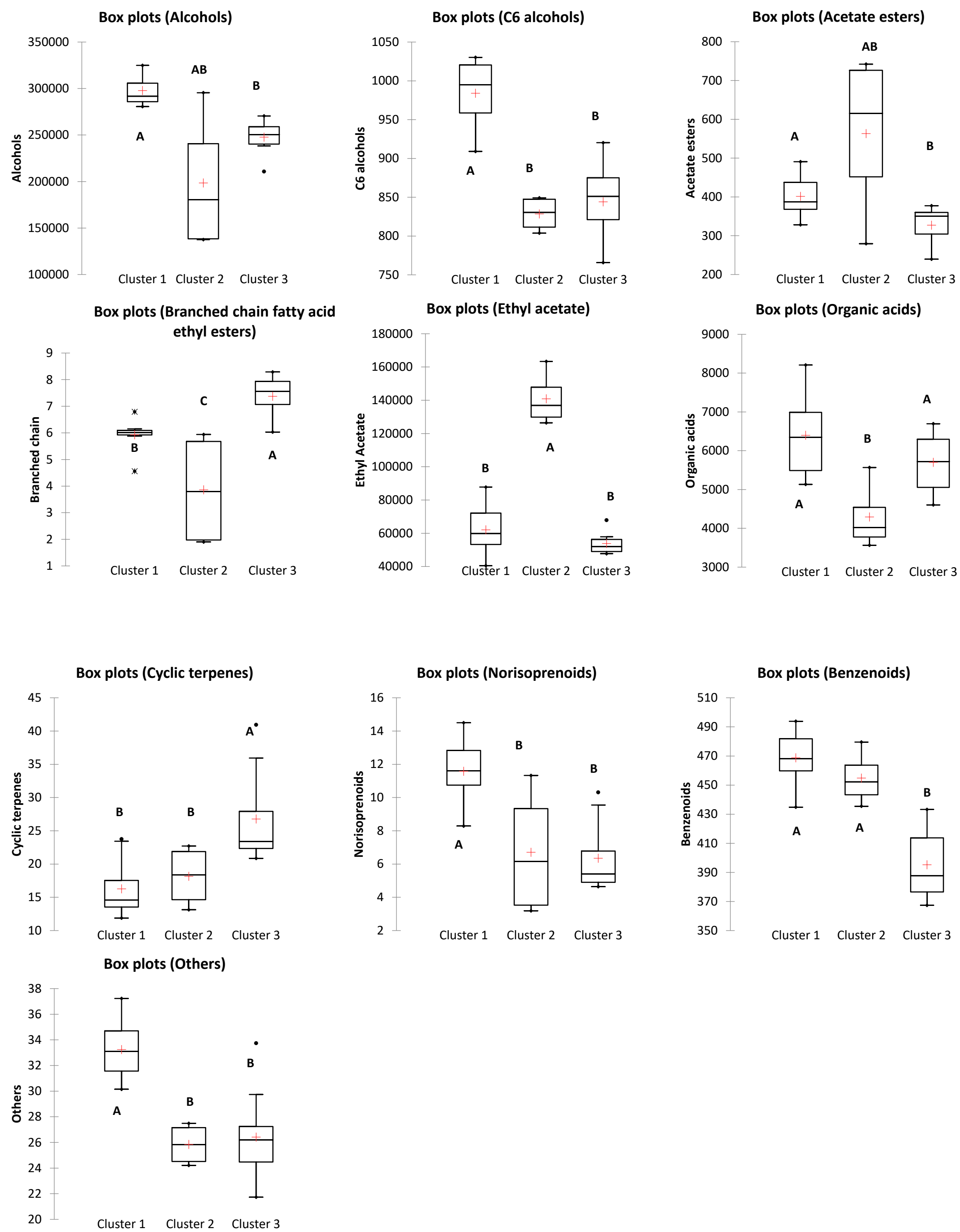


Figure 3.3.2.5. Box Plot of chemical classes with significant differences (capital letters) according to Mann-Withney test (α=0.05) of Corvina HCA clusters.

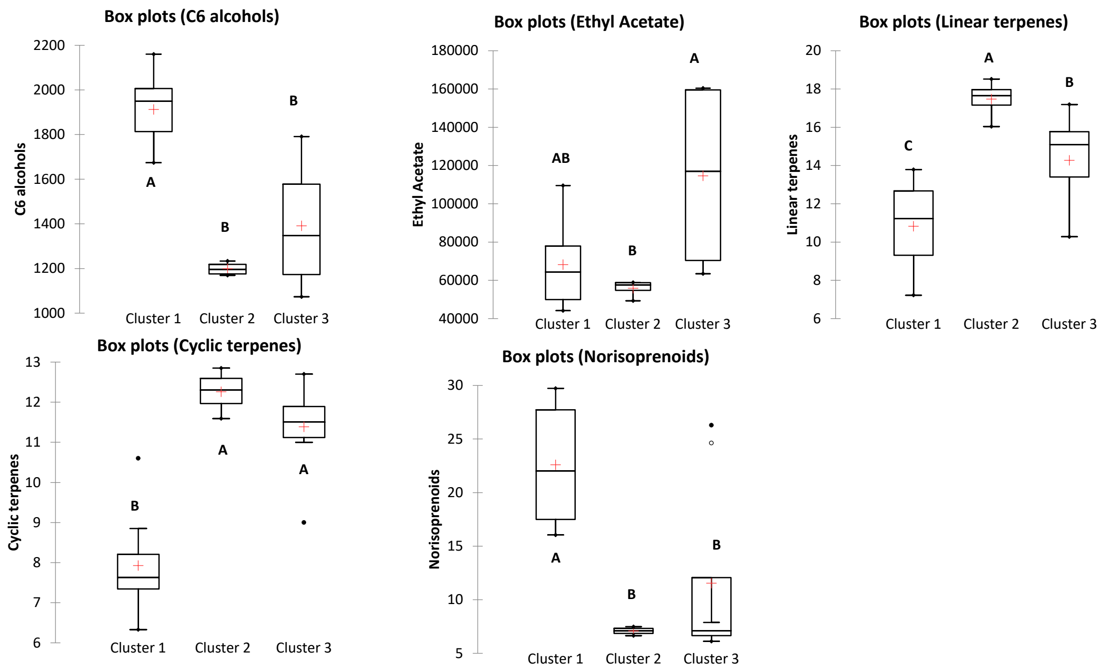


Figure 3.3.2.6. Box Plot of chemical classes with significant differences (capital letters) according to Mann-Withney test (α=0.05) of Corvinone HCA clusters.

3.5. Conclusion

- From a chemical point of view, most volatile compounds that are thought to influence wine aroma were primarily affected by grape composition. Although this might be expected for volatile compounds primarily deriving from grape, for example terpenes, our results highlight a clear influence of grape composition also on volatile compounds of fermentative origin, in particular acetate esters.
- The contribution of yeast is lower than that associated with grapes, and only for some compounds and not for both varieties yeast had a systematic impact. One strain was characterized by increased ester production in all fermentations, which is of great sensory relevance considering the high aroma impact of esters.
- Sensory analysis also confirmed that grape composition had a major influence than employed yeast
- Although it is believed that spontaneous fermentations can enhance the expression of wine geographical identity, in our study, spontaneous fermentations were characterized by high concentration of ethyl acetate regardless of grape variety and area of origin, which should be carefully considered by winemakers. In withered grapes wine also showed higher acetic acid content, above the odor threshold. Sensory results indicated loss of the diversity associated with grape origin due to spontaneous fermentation.

Chapter 4

Aging effect on aroma chemical signature

4.1. Introduction and aim

Unlike most of other foods, wine sensory quality is thought to reach a peak after an aging period. The rate at which this maximum quality is reached and maintained is not the same for all wines but it varies depending on the wines and conservation parameters (Ugliano, 2013).

Aging is defined as the period between the end alcoholic fermentation and consumption. Its duration is extremely variable according to the origin, composition and quality of the wine considered. Aging is a very common practice in Valpolicella and some production disciplinary require wines to go through a minimum period of aging before being released on the market. The “Valpolicella” appellation requires at least one year of aging, the “Valpolicella Ripasso” at least 2 year of aging and the "Amarone della Valpolicella" must be subjected to a minimum period of aging of at least 2 years, which can be extended to 4 years for the "riserva" version. Although the production regulations do not make it compulsory, many Valpolicella wines, Amarone in particular, often undergo a period of wood aging. This practice has an important impact on wine aroma, colour, stability and clarification (Ribereau-Gayon, et *al*., 2006). During this study the effect of wood contact will not be considered, but other concurrent phenomena will. In fact, during aging period many other changes in the composition of wine take place, resulting in the evolution of colour, aroma and taste. In particular, aroma undergoes dramatic changes through a wide range of acid hydrolysis reactions, cyclization, acid-catalysed rearrangements and oxidations, that to date are only partly understood, involving an equally wide range of compounds of different biochemical origins, both varietal and fermentative (Skouroumounis, *et al*., 2000) (Winterhalter, *et al*., 1997) (Winterhalter, 1991). Esters are among the compounds most affected by aging. Depending on temperatures, pH and by the equilibrium concentrations of esters and corresponding alcohols and acids the fate of acetate and ethyl esters is usually hydrolysis and the consequent decrease (Ramey, *et al*., 1980) (Marais, 1978). On the contrary branched chain fatty acid ethyl esters during wine aging may increase depending on the initial concentration of the corresponding branched chain fatty acid (Shinohara et. *al.,* 2007) (Kotséridis, 1999). Another key phenomenon during aging is the release of volatile compounds from glycosidic precursors due to acid hydrolysis of sugar moiety and aglycone. The latter can be a monoterpene, C_{13} norisoprenoids, aliphatic alcohols or benzene derivatives (Ugliano, 2009). Terpenes evolution during aging is complex and depends both on the hydrolysis of precursors, which often lead to an increase in these compounds during the early stages of aging, but also on various hydration and dehydration reactions that result in decreases and radical changes in the terpene pool.

In **Chapter 1** the existence of aroma chemical signatures of wine geographical identity has been demonstrated for single vineyard Valpolicella red wines. As this was done on young wines, in the first months after winemaking, the question arises as to whether this typicality would be maintained with aging, which can substantially modify wine volatile metabolic profile. In order to address this question, and considering that for wines of the 2019 vintage the timeframe of the thesis project would have not allowed any significant aging period, accelerated aging protocols were applied. These have been successfully used in a number of studies (Ferreira, *et al*., 2004) (Ferreira, *et al*., 2008) (Loscos, *et al*., 2010), also for Valpolicella wines (Slaghenaufi, *et al*., 2018) (Slaghenaufi, *et al*., 2019) (Slaghenaufi, *et al*., 2020), to study the evolution of relevant aroma compounds. In our case, two protocols were applied, one involving mild conditions, the other involving harsher conditions. The combined information obtained was used to investigate the fate of some volatile compounds important for the aromatic profile of Valpolicella wine including esters, terpenes and norisoprenoids.

4.2. Materials and methods

4.2.1. Wine aging protocols

Two different ageing protocols were employed during this study.

Protocol 1

This mild accelerated aging protocol was based on the procedure described by Slaghenaufi *et al*. (2019). One-hundred fifteen mL of wine were placed in glass vial and crimped leaving 0.8 mL of headspace corresponding to 2 mg/L of oxygen. Vials were crimped and sealed with epoxy resin. Sample vials were placed at 16°C and 40 °C for 30 days. All the wine described in Chapter 1, namely Corvina and Corvinone from fresh and withered grapes, from the three vintages 2017-2019 and five vineyards (V1-V5), were submitted to model aging. For each wine, biological replicates were pooled to obtain one single representative sample, which was then divided in two aliquots, one labelled 'young' and stored at 16 °C (**T16**), the other second labelled 'aged'" **(T40**), stored at 40 °C (**Table 4.2.1**). The storage lasted 30 days and the entire experiment was carried out in duplicate.

Protocol 2

The protocol proposed by Silva Ferreira *et al*. (2003) was applied, with minor differences. Twenty-five millilitres of wine were placed in glass vial and crimped. The crimped cap was further sealed with Araldite glue to prevent any oxygen transfer. Sample vials were then placed at 60°C (±0.2°C) for 0, 48, 72, and 168 h. The experiment was carried out in duplicate for each wine, which was the pool of the corresponding biological replicates. Only 2018 and 2019 wines of Corvina and Corvinone from fresh grapes were studied (**Table 4.2.1**).

Table 4.2.1. Summary of studied wines

Protocol 1				
Vineyards	**Varieties**	**Vintages**	**Grape treatments**	**Aging tratments**
V1-V2-V3-V4-V5	Corvina, Corvinone	2017-2018-2019	Fresh and withered	16°C and 40°C for 30 days
Protocol 2				
Vineyards	**Varieties**	**Vintages**	**Grape treatments**	**Aging tratmentents**
V1-V2-V3-V4-V5	Corvina, Corvinone	2018-2019	Fresh	60°C for 0, 48, 72, and 168 h

4.2.2. Analysis of free and bound volatile compounds by SPE–GC-MS and SPME-GC-MS.

SPE–GC-MS and SPME-GC-MS analysis of free and bound volatile compounds have been performed as reported in ***Chapter 1-Materials and methods***.

4.2.3. Statistical analysis

Principal Component Analysis (PCA), Kruskal Wallis (α=0.05) and Mann-Whitney test (α=0.05) of chemical data have been performed using XLSTAT 2017(Addinsoft SARL, Paris, France).

4.3. Results and discussion

4.3.1. Aging influence on aroma chemical signatures of wine geographical origin

Under conditions of mild accelerated aging, namely storage of the wines at 40 °C for 30 days with 2 mg/L of oxygen (protocol 1), major changes to wine volatile composition were observed for Corvina and Corvinone wines from fresh and withered grapes (**Appendix 4.3.1-4.3.14**). An overview of these changes, as obtained by PCA of compounds showing statistically significant differences, is given in **Figure 4.3.1**. Compared to wines stored at 16 °C (referred to as 'young' wines), aged samples were characterized by increased content of cyclic terpenes such as 1,4- and 1,8-cineole, p-cymene and p-menthane-1,8-diol, branched chain fatty acids ethyl esters, the norisoprenoids TDN, TPB, vitispirane, and various benzenoids including 2,6-dimethoxyphenols. These increases reflect acid catalysed reactions involving different volatile compounds (for example linear monoterpene alcohols or branched chain fatty acids) as well as non-volatile glycoside precursors (Díaz-Maroto, *et al*., 2005) (Slaghenaufi, *et al*., 2018).

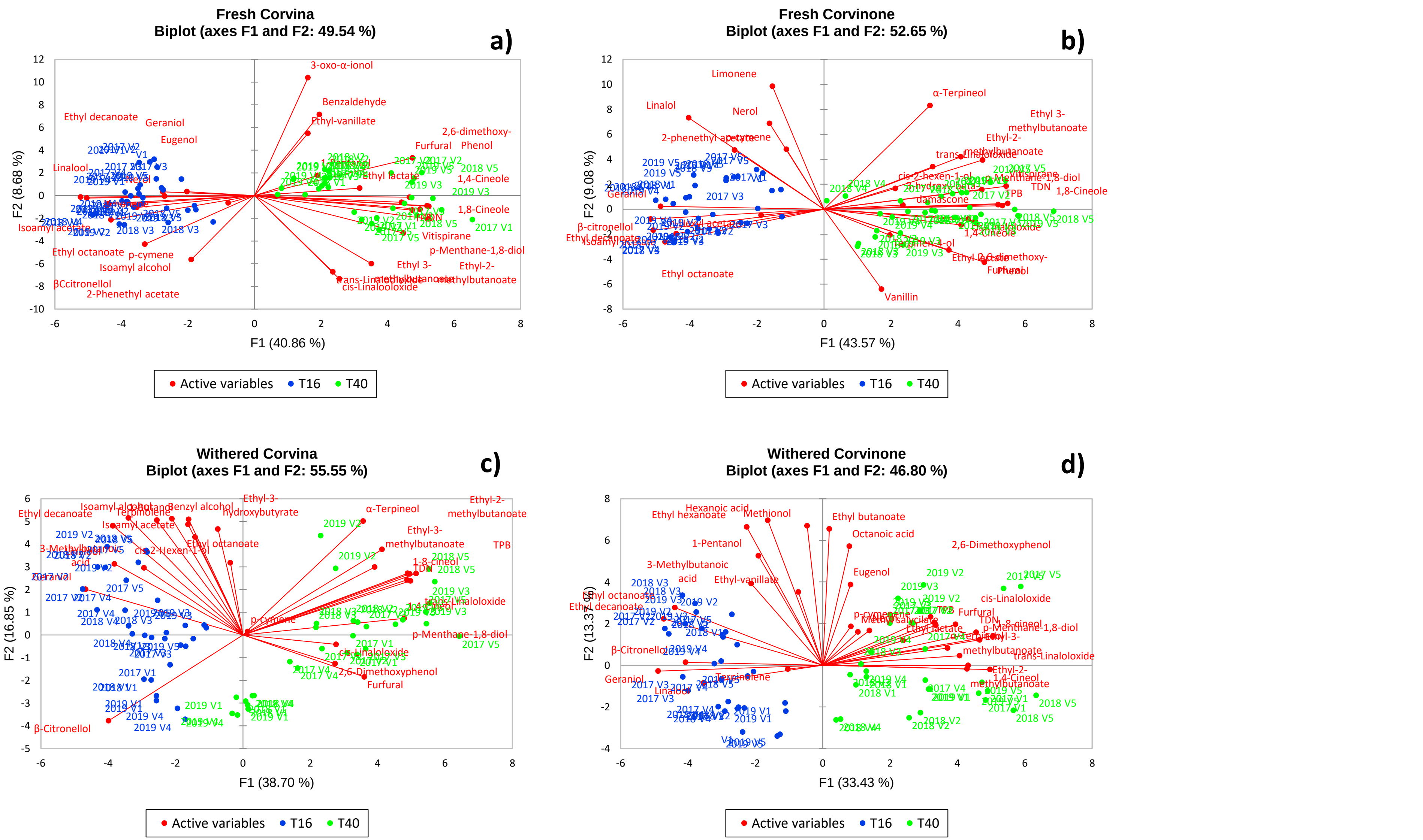


Figure 4.3.1. PCA analysis performed with significant different compounds between varieties of T16 and T40 a) fresh Corvina wines, b) fresh Corvinone wines, c) withered Corvina wines and d) withered Corvinone wines. Data of each vintage were individually rescaled (from 0 to 100).

In **Chapter 1** we have shown that several of these compounds play a central role in the composition of the aroma chemical signatures that characterized young wines geographical identity. Therefore, it can be expected that aging could modify the aroma chemical signature of wines, either reducing or increasing the chemical diversity observed. Using the same data treatment approach previously described in Chapter 1, in which data of each vintage before multivariate analysis have been rescaled from 0 to 100, and aggregated into a single matrix, the aroma chemical signatures of the different geographical origins were built for each varietal wine, and are shown in **Figures 4.3.2** and **4.3.3** for fresh and withered grape wines respectively. Generally speaking, aroma signatures of individual geographical origin were preserved to a good extent after aging, with separation between wines of each vineyard clearly observed in most cases. In particular, in the case of Corvina wines, two main clusters could be observed along PC1, one consisting of V2, V3, V5, and the other of V1 and V4. Within each cluster different vineyards were separated on PC2. In the case of Corvinone wines V5 wines were always clearly separated from the other samples, as it was to a lesser extent V3. It is worth mentioning that, in the case of Corvina, the plot has strong similarities with that of young wine (**Figure 1.3.6**), although a little more overlapped. In fact, V1 and V4 lie close on the plot, as well as V2 and V3 and V3 and V5. Conversely, in the case of Corvinone, V1-V3 which in young wine formed a single overlapping group, with aging formed individual clusters, quite well separated. In this particular case, while it would seem that in Corvina, ageing slightly reduced the diversity associated with vineyard signature, in Corvinone it would seem to have enhanced it. In any case, the fact that the vineyard signature was not lost with ageing is certainly a point of great interest, since a period of ageing is mandatory for most of the red wines of Valpolicella.

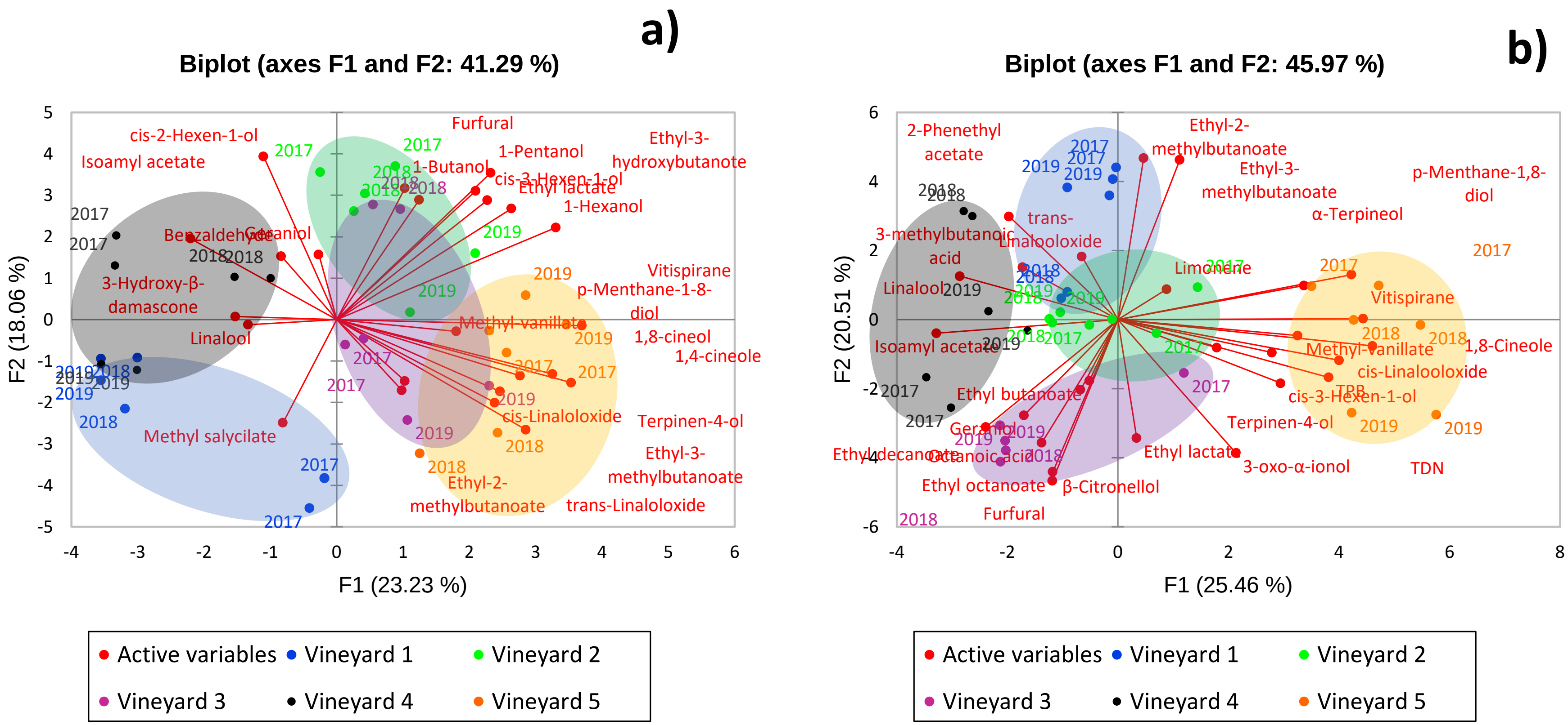


Figure 4.3.2.PCA analysis of aged (T40) a) Corvina and b) Corvinone fresh grape wines with significant different compounds. Circles in observations plot are not the result of statistical processing but are useful for a better understanding of the plot

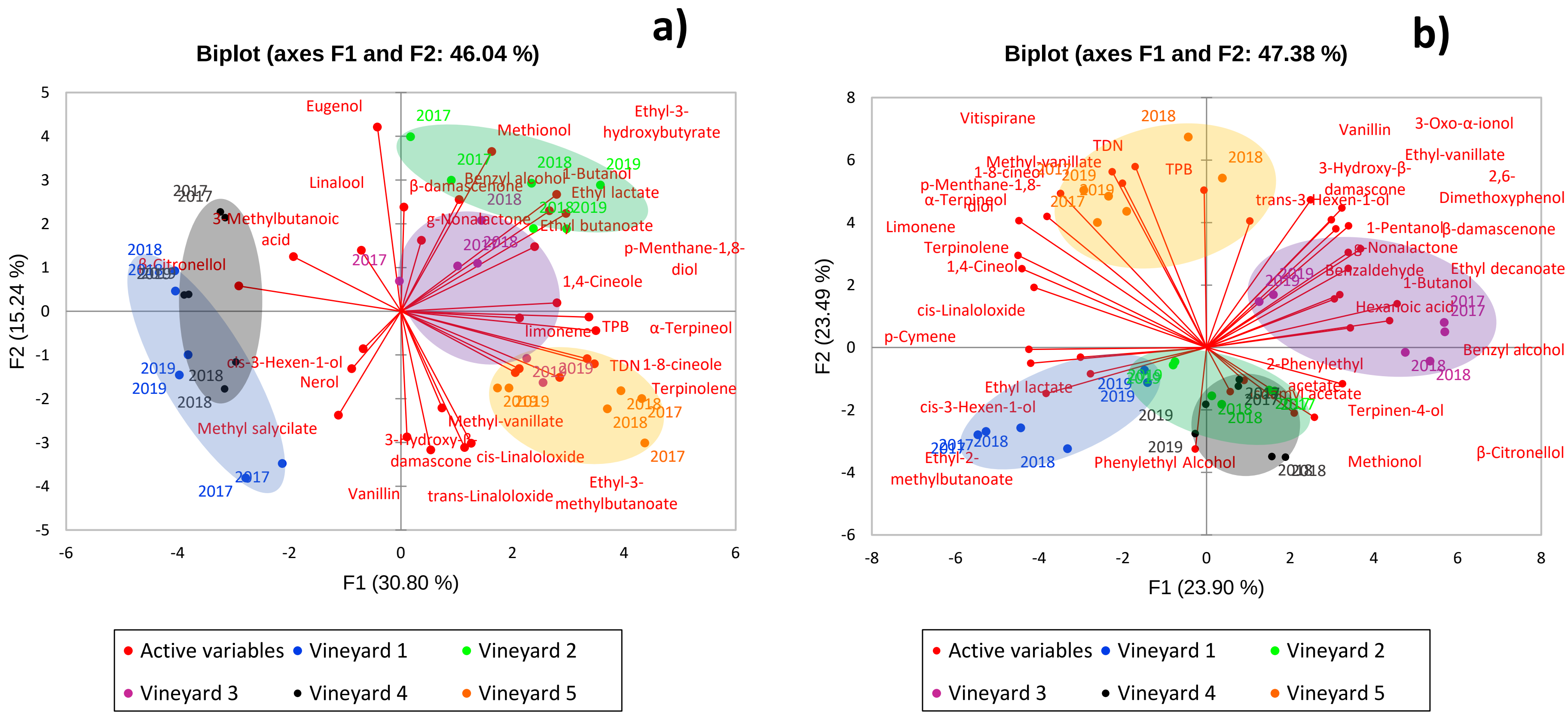


Figure 4.3.3. PCA analysis of aged (T40) a) Corvina and b) Corvinone withered grape wines with significant different compounds. Circles in observations plot are not the result of statistical processing but are useful for a better understanding of the plot

Terpenes and norisoprenoids were at the same times among the main drivers of vineyard signatures and among the compounds most affected by ageing treatments, as already reported by literature (Slaghenaufi, *et al*., 2018) (Moyano, *et al*., 2002) (Park, *et al*., 1993). Aged induced a significant decrease of many terpenes such as linalool, geraniol and β-citronellol. As shown in **Figure 4.3.4** linalool decreased in all the wines after aging. However, not only the absolute contents changed with aging, but also the patterns. In fact, while in young wine it was an important driver of vineyard signature associated with V5 in both Corvina and Corvinone in aged wines it didn't. Geraniol content, which we identified in the first chapter as a typicality driver, after ageing was not detected or below 1 µg/L.

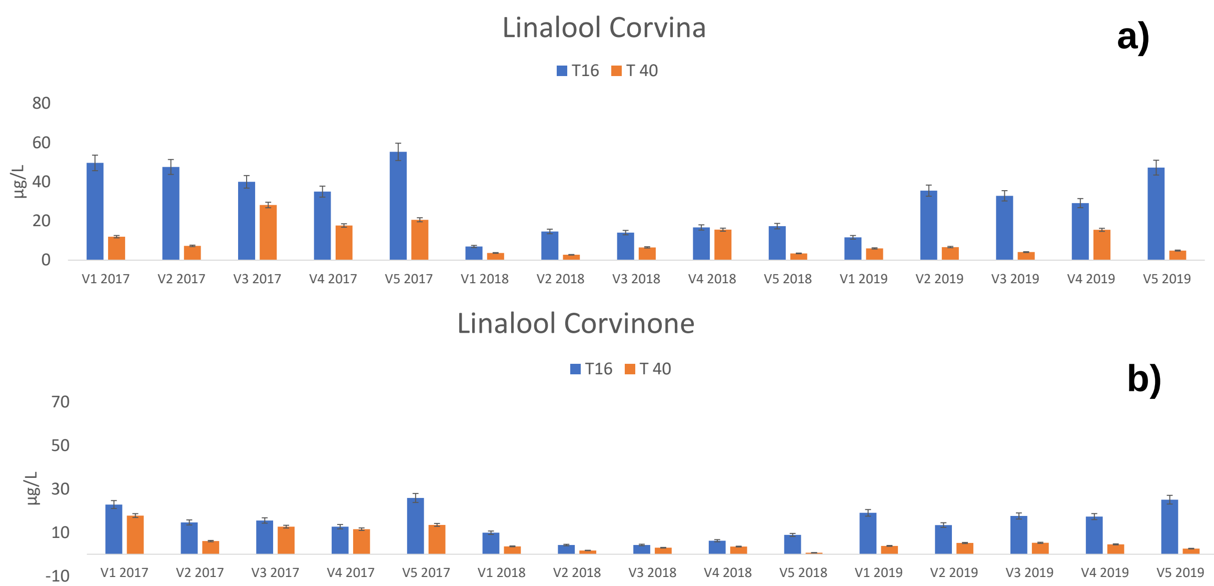


Figure 4.3.4. Linalool content in young (T16) and aged (T40) a) Corvina and b) Corvinone wines. V1-V5 is short for vineyard 1- vineyard 5

While many terpenes decreased, some that were previously absent or present in very low concentrations increased, such as p-menthane-1,8-diol, 1,4- and 1,8-cineole (**Figure 4.3.5**). Some authors studied the occurrence of these compounds in red wines (Antalick, *et al*., 2015) (Fariña, *et al*., 2005). Slaghenaufi & Ugliano (2018) indicated them as important contributors to balsamic aromas in Valpolicella aged wines, proposing a formation pathway involving certain terpenes, linalool in particular, and in which p-menthane-1,8-diol is an odourless intermediate in the formation of balsamic cineoles.

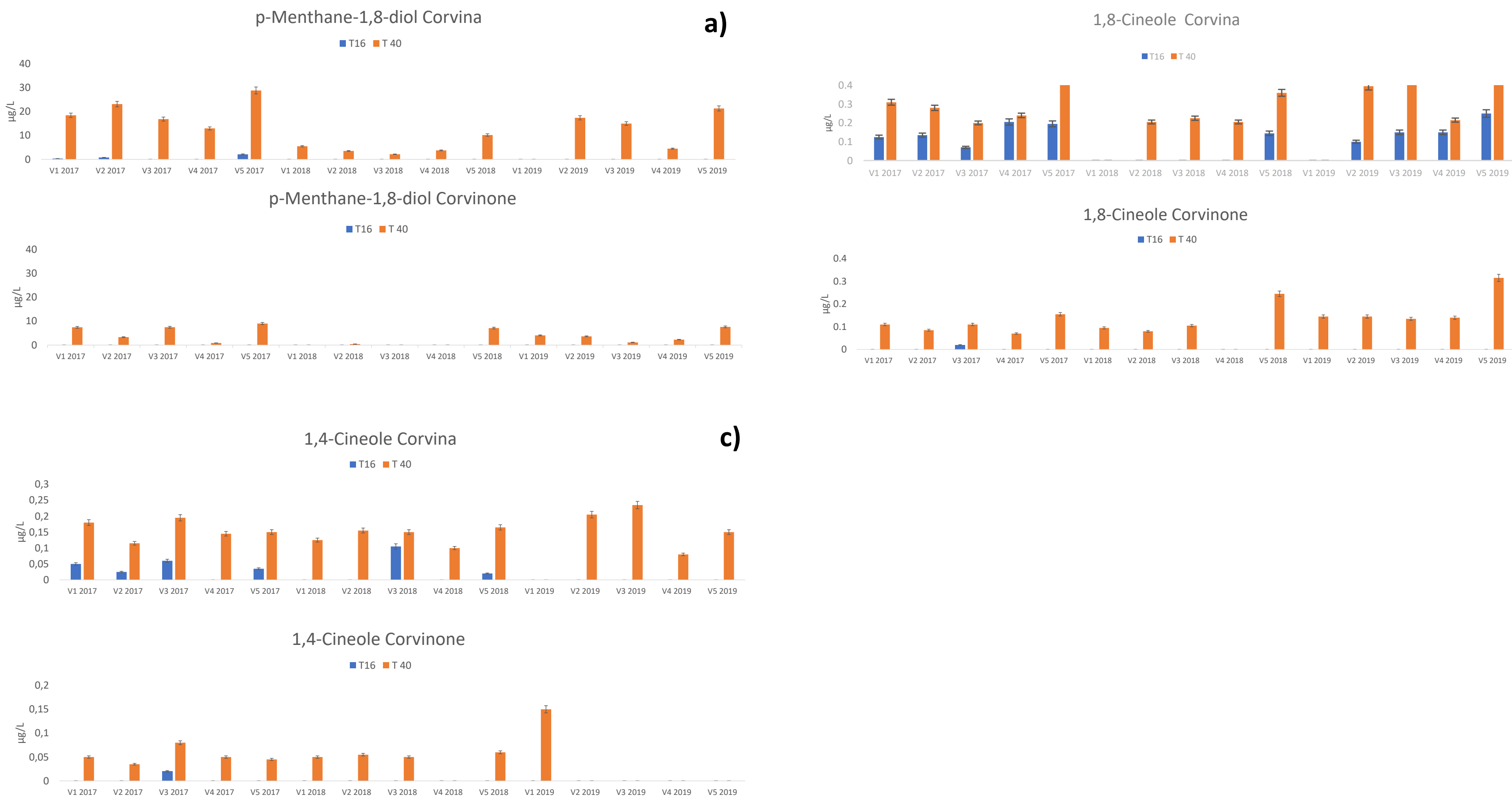


Figure 4.3.5. a) p-Menthane-1,8-diol, b) 1,8-cineole and c) 1,4-cineole content in young (T16) and aged (T40) wines

The results of the present work provide further evidence for this pathway, an example being provided by the study of the relationships between these compounds in wines from fresh grapes. In fact, p-menthane-1,8-diol in aged was very well correlated with linalool in young wines, with high coefficients of correlation in both varieties (R^2=0.8008) (**Figure 4.3.6**).

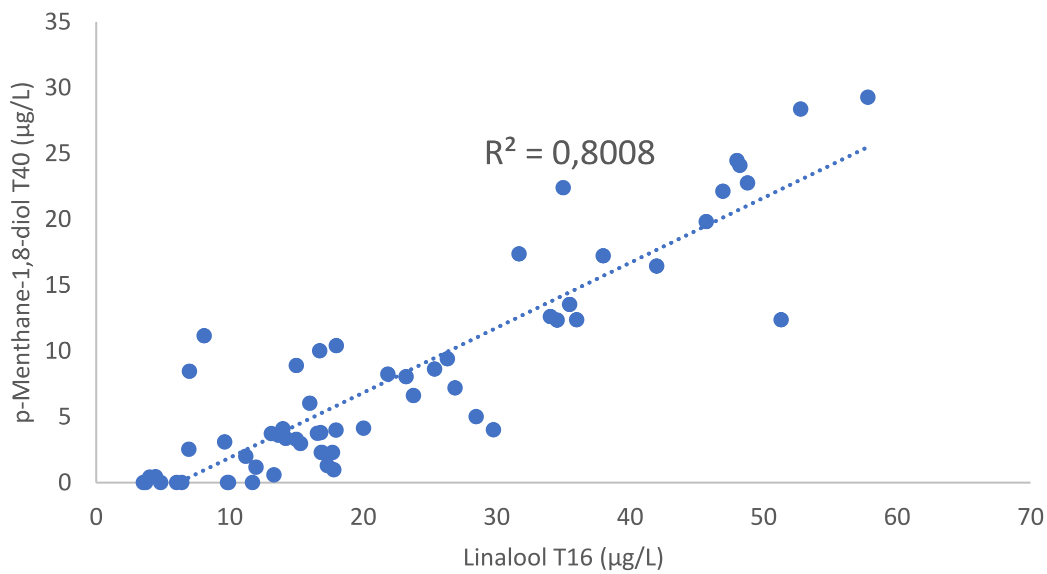


Figure 4.3.6. Correlation between linalool in T16 wines and p-menthane-1,8-diol in T40 wines in fresh grape wines.

Accordingly, linalool emerges as one central component of the aroma chemical signature of both young and aged wines: in young wines this compound is a direct driver of geographical origin signature (and most likely also contributing to perceived aroma), whereas in aged wines it contributes to the formation of p-menthane-1,8-diol and eventually to cineoles. 1,8-Cineole in aged wines showed significant but relatively weak correlation with linalool content when considering 2017, 2018 and 2019 vintage altogether (R^2=0.449), but in each vintage much stronger correlations were observed (**Figure 4.3.7**).

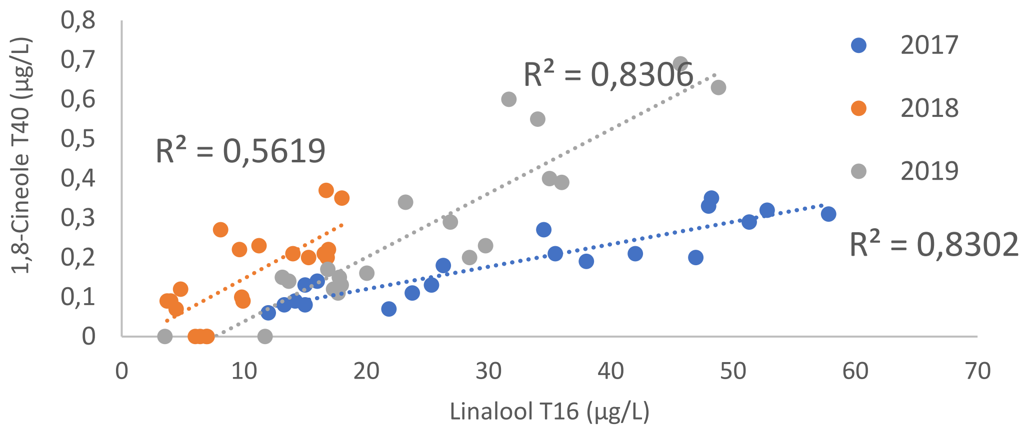


Figure 4.3.7. Correlations between linalool in T16 wines and 1,8-cineole in T40 wines in the three different vintages

This is reflecting the fact that the kinetics of cineole accumulation are depending on linalool initial concentration, which is in turn affected by vintage. In the case of 1,4-cineole (**Figure 4.3.8)** strong correlation with linalool was observed only in vintage 2017 (R^2=0.795), while in vintage 2018 and 2019 it had an R^2 lower than 0.5. Finally, a good correlation was observed between p-menthane-1,8-diol and 1,8-cineole in wine after aging was observed (R^2=0.5641) (**Figure 4.3.9).**

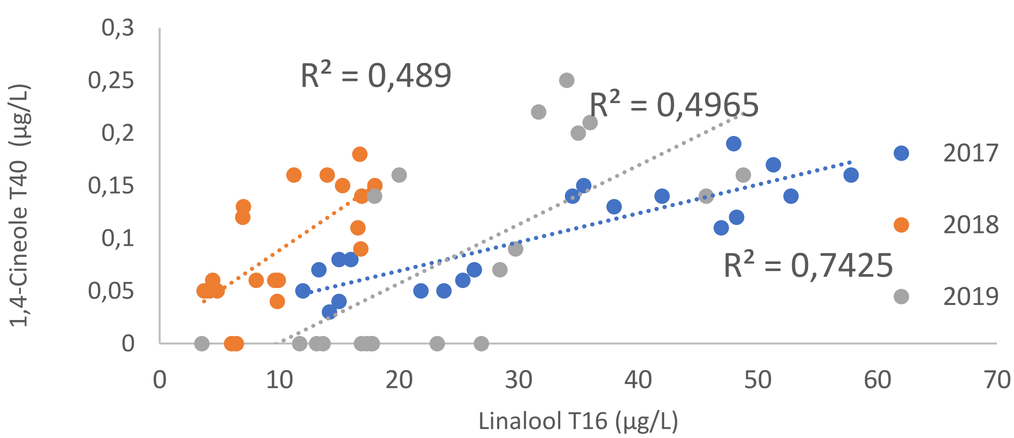


Figure 4.3.8. Correlations between linalool in T16 wines and 1,4-cineole in T40 wines in the three different vintages,

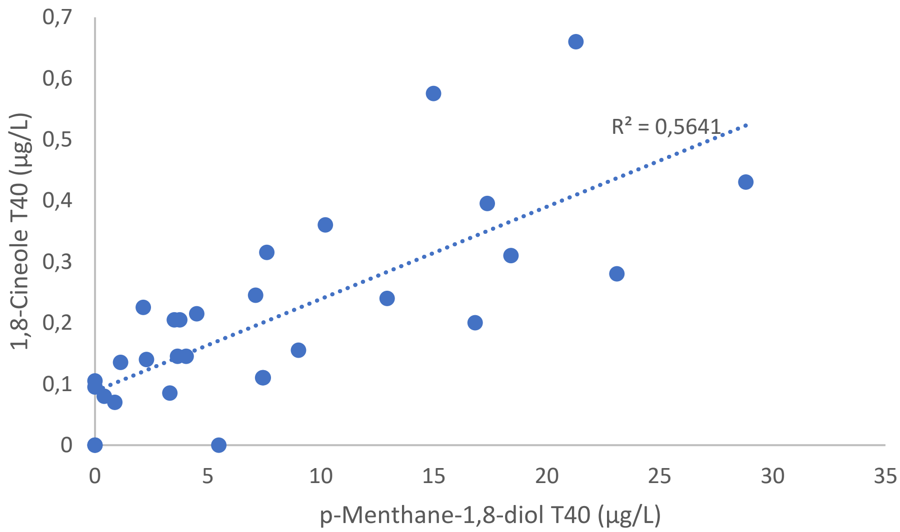


Figure 4.3.9. Correlation between p-menthane-1,8-diol and 1,8-cineole in T40 wines.

Further insights in the behaviour of these compounds during aging were obtained applying aging protocol 2, in which stronger conditions were employed and volatile evolution was monitored at several timepoints. This approach allowed to model with more detail the evolution of the different volatiles. The data in **Figure 4.3.10** and **4.3.11** allowed to highlight additional relevant aspects of the behaviour of these molecules during aging.

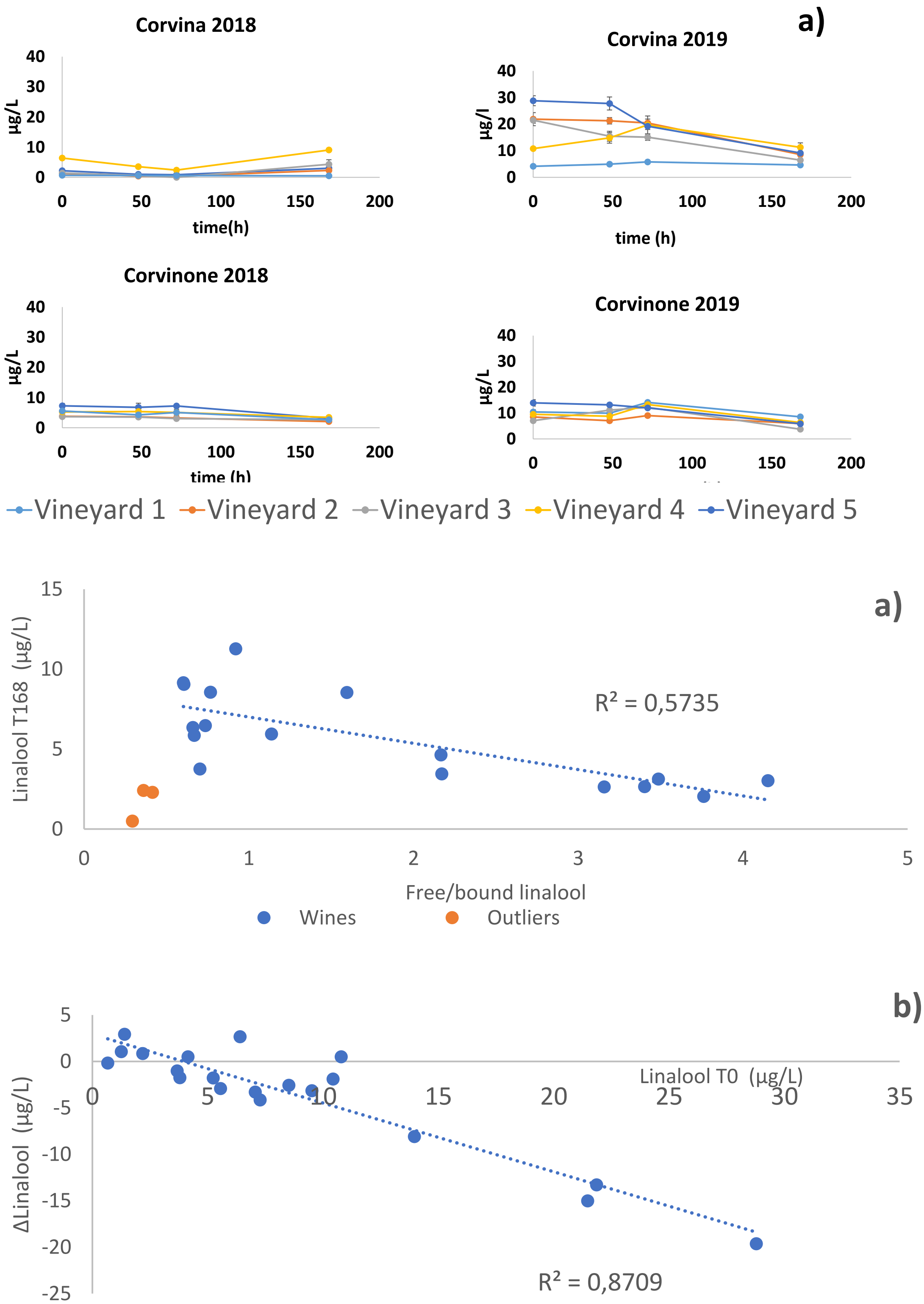


Figure 4.3.10. a) Evolution of linalool during wine aging. b) Correlation between free/bound ratio of linalool at T0 and linalool at T168. c) Correlation between linalool at T0 and Δ (T0-T168) linalool

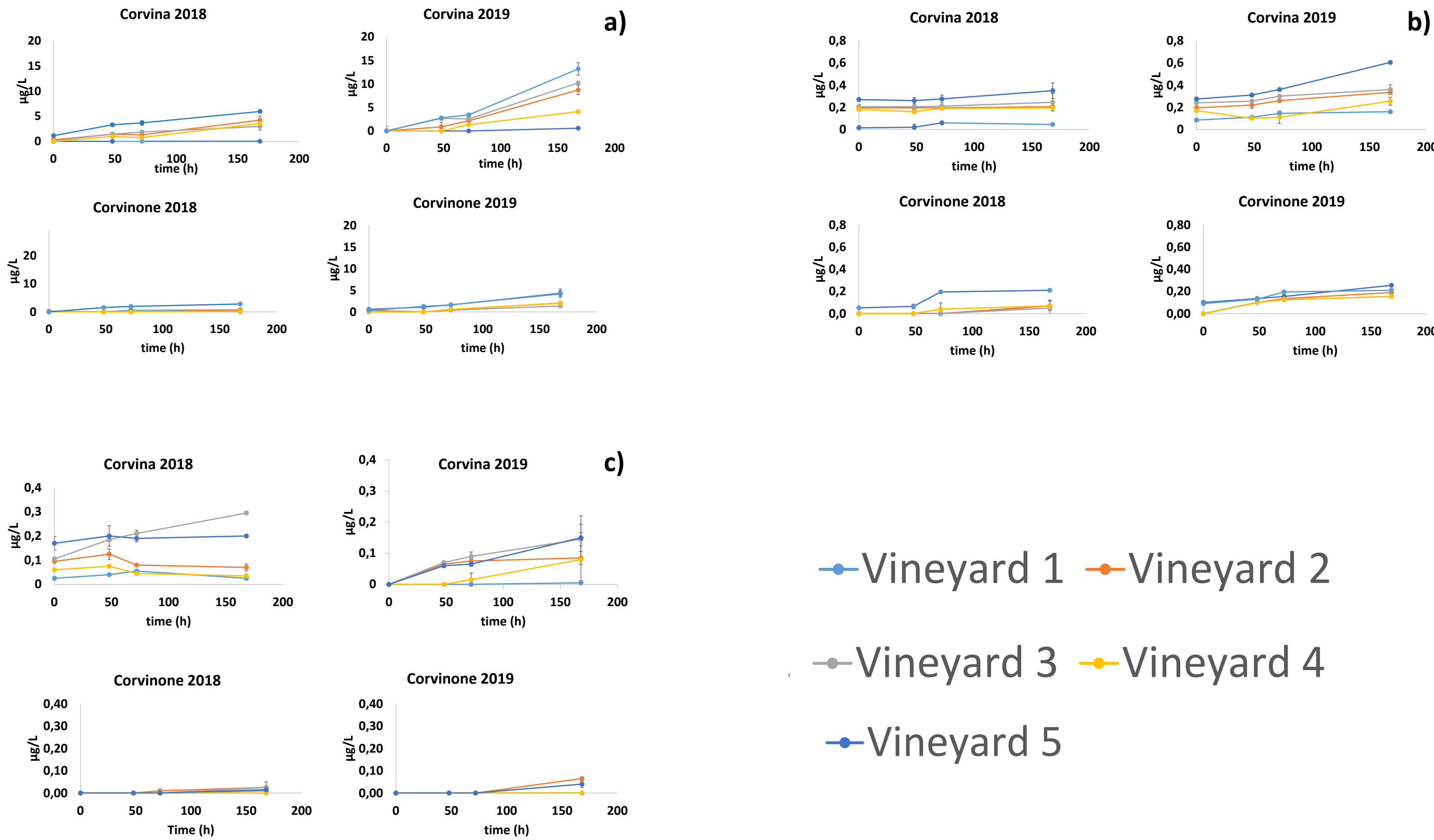


Figure 4.3.11. Evolution of a) p-menthane-1,8-diol b) 1,8-cineole and c)1,4-cineole during wine aging

- The concentration of linalool at the end of aging treatment (168 h) is well correlated with the free/bound ratio of linalool at T0 (R^2=0.5735), and this correlation is higher than the one observed for either free or bound linalool alone (**Figure 4.3.12**), indicating that available linalool during aging is impacted also by bound forms. Three outliers were however found belonging to Corvina 2018 (vineyards 2, 3 and 5). These outliers shared very low concentration of free linalool, around 1 ug/L, already at time zero before the ageing treatment.
- A high correlation between delta free linalool (t0-t168) and free linalool at the beginning of ageing has been also identified (R^2=0.8709).
- α-Terpineol is also well correlated to cineoles and p-menthane-1,8-diol (**Figure 4.3.12**), and this compound is probably the first intermediate in the reaction of linalool to p-menthane-1,8-diol

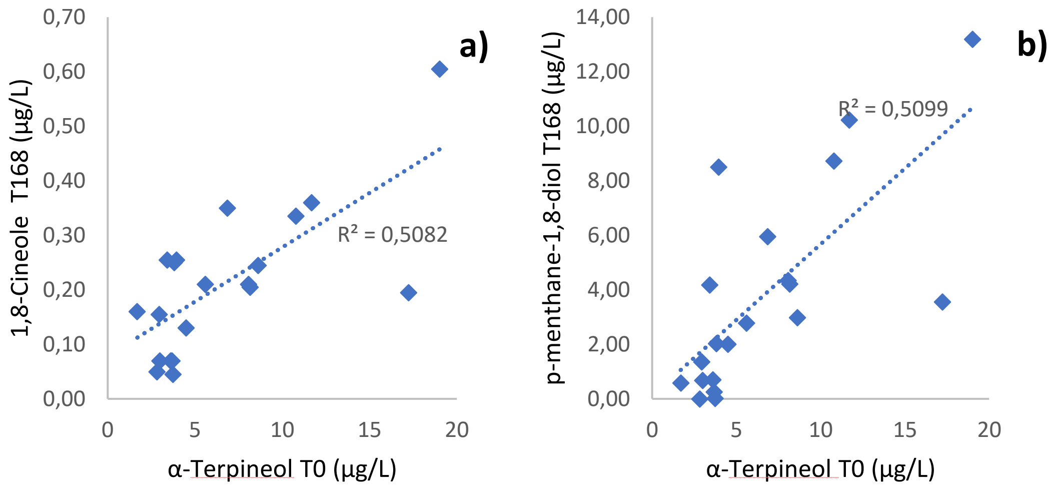


Figure 4.3.12. Correlations between a) α-terpineol(T0) and p-menthane-1,8-diol (T168) b) α-terpineol (T168) and 1,8-cineole (T40)

- p-Menth-1,8-diol and the two cineoles are very well correlated (**Table 4.3.1**) and show in most cases an ongoing increase, indicating further potential to contribute to wine aroma development during long term aging

Table 4.3.1. Correlation between 1,4- and 1,8-cineole with p-Menthane 1,8diol

	p-Menthane-1,8-diol							
	R^2				Correlation matrix			
	0h	48h	72h	168h	0h	48h	72h	168h
1,4-Cineole	**0.415**	**0.477**	**0.423**	**0.441**	**0.645**	**0.691**	**0.651**	**0.664**
1,8-Cineole	0.083	**0.703**	**0.754**	**0.898**	0.288	**0.839**	**0.869**	**0.948**

Based on these evidences, a pathway for cineoles formation is proposed in **Figure 4.3.13**.

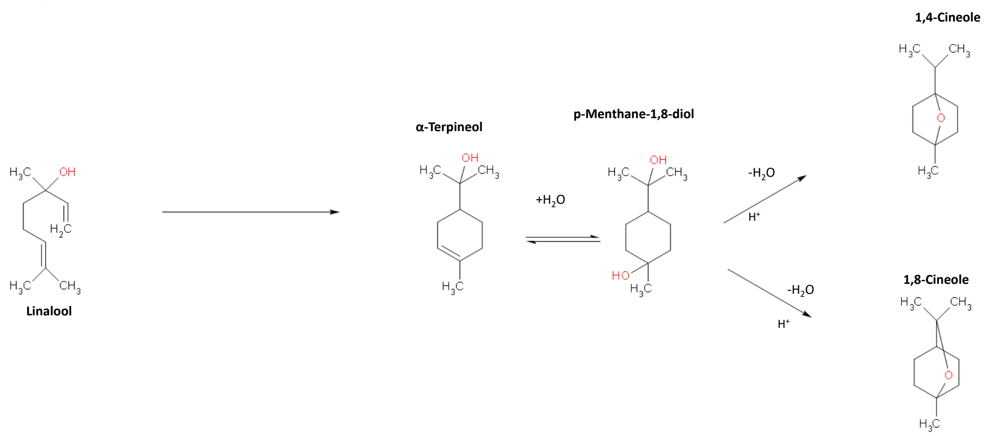


Figure 4.3.13. Proposed cineoles formation pathway

Aging in mild hydrolytic conditions (protocol 1) also affected several norisoprenoids. β-Damascenone, the main norisoprenoid, showed little difference between young and aged wines. Conversely, a strong increase in all non-megastigmane norisoprenoids, namely vitispirane, TDN and TPB was observed in all varieties and vintages in aged wines (**Figure 4.3.14)**. Despite these wide quantitative variations of all this three norisoprenoids, they showed very similar pattern in young and aged wines, their content in young wines being well correlated with aged wines (R^2=0.807 for vitispirane, R^2=0.5842 for TDN and R^2=0.5414 for TPB) (**Figure 4.3.15**). An increase of these norisoprenoids was already found in many other studies (Ferreira, *et al.*, 2008) (Mendes Pinto, 2009) (Loscos, *et al.*, 2010).

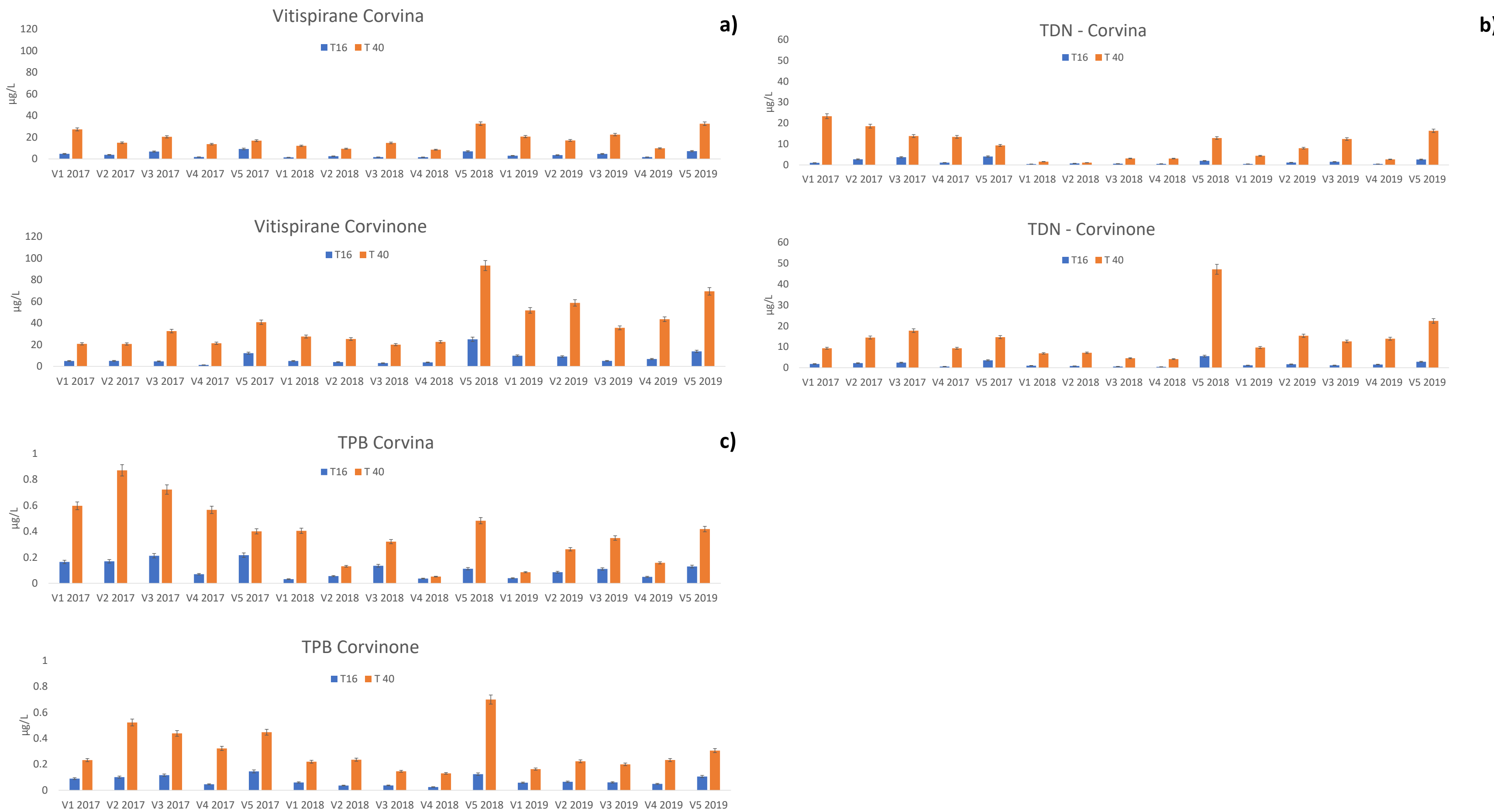


Figure 4.3.14. a) Vitispirane b) TDN and c) TPB content in young (T16) and aged (T40) wines.

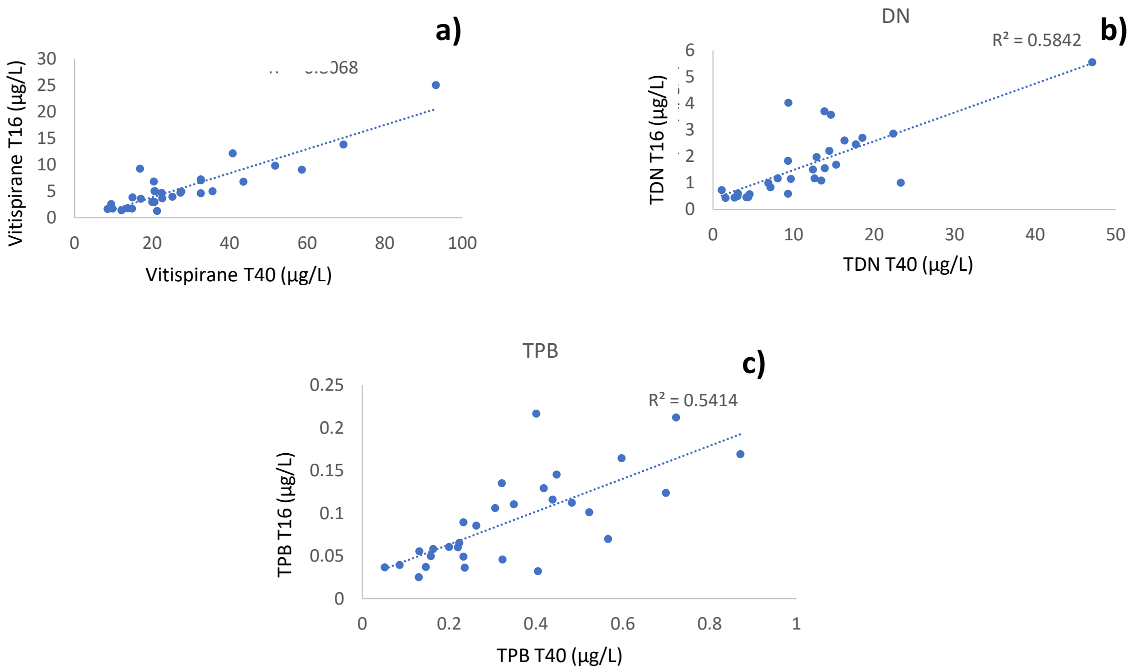


Figure 4.3.15. Correlations between T16 and T40 free a) Vitispirane, b) TDN and c) TPB

The experiment under harsh temperature conditions (protocol 2) indicated however that when damascenone was present at initial concentraitons higher than approx. 5 µg/L its concentration is likely to decrease over time, reaching a plateau in the 2-5 µg/L range (**Figure 4.3.16**). Vitispirane and TPB showed a trend of consistent increase in Corvinone, whereas they were either stable or decreasing in Corvina (**Figure 4.3.16**). This pattern suggest that aroma attributes associated with tobacco and camphor odor attributes could be more characteristc of the aging of Corvinone wines, an aspect to be considered in blending decisions.

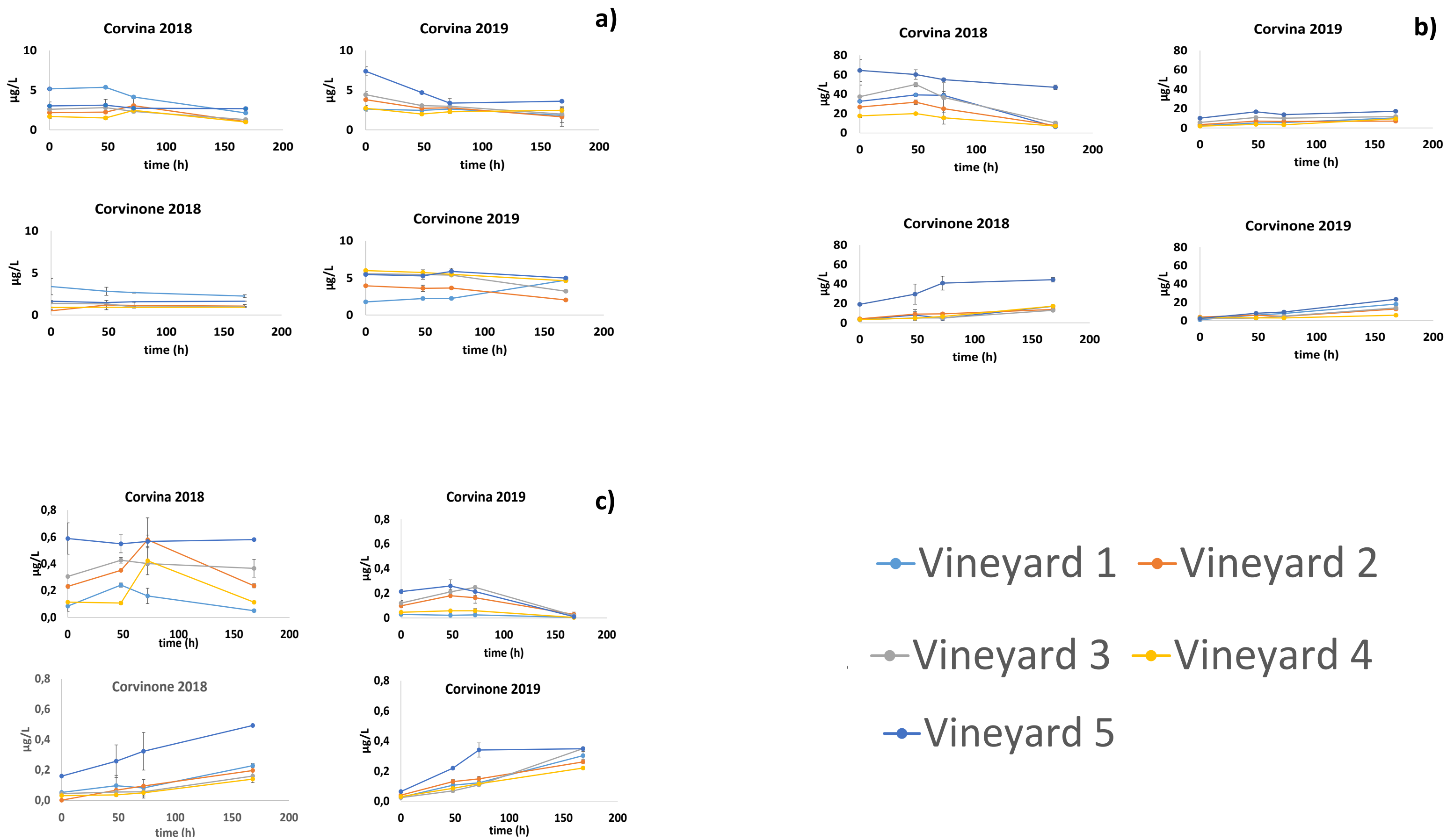


Figure 4.3.16. Evolution of a) β-damascenone b) Vitispirane and c) TPB during wine aging

Finally, esters were much affected by aging treatment, with branched-chain fatty acids ethyl esters, namely ethyl-2- and ethyl-3-methylbutanoate, showing significantly higher content in almost all wines. The increase of these esters during ageing has been already been reported (Díaz-Maroto, *et al.*, 2005) and is a consequence of the esterification reaction of the corresponding acids with ethanol. However, a correlation between individual esters and their precursor acid was difficult to establish, due to the hugely different concertation range of the two compounds. Nevertheless, an extremely strong and significant correlation (R^2= 0.9168) between the content of these compounds in the young vs. aged wine was observed, suggesting that chemical esterification plays a key role in the formation of these esters, probably also during fermentation (**Figure 4.3.17**)

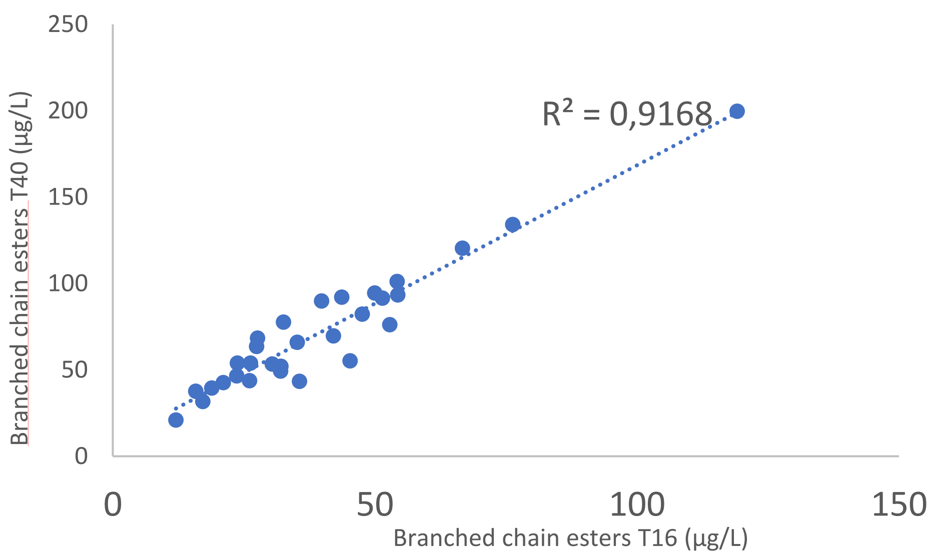


Figure 4.3.17. Correlation between total fatty acids branched chain ethyl esters in T16 and T40 wines

As expected, both acetate and ethyl esters in aged wines showed a lower content compared with young wines, due to acid hydrolysis (Styger, *et al*., 2011). While the content of some of them, like isoamyl acetate, ethyl octanoate and ethyl decanoate has been particularly impacted, the content of other esters like ethyl butanoate or hexanoate did not. Isoamyl acetate patterns in the young and aged wines were quite similar, a good correlation between the initial content of this ester and the content after ageing was found (**Figures 4.3.18)**. Ethyl octanoate and decanoate were the ethyl esters that showed significant differences between young and aged wines. Like isoamyl acetate also ethyl octanoate and total ethyl esters showed similar patterns in young and aged wines (**Figures 4.3.18**).

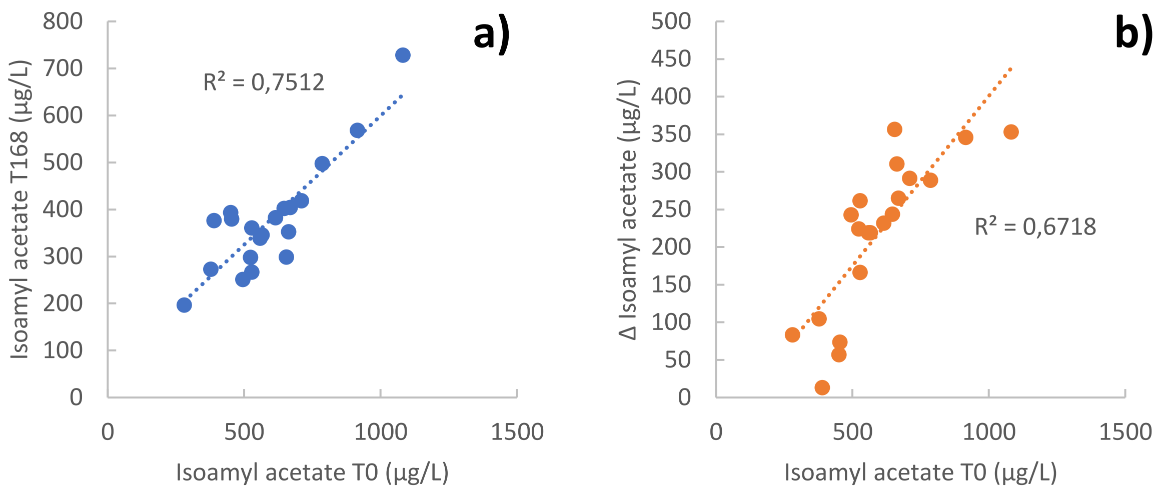


Figure 4.3.18. Correlation between isoamyl acetate concentration in T0 wines (µg/L) and a) isoamyl acetate concentration in T168 wines(µg/L) and b) Δ concentration (T0-T168) of isoamyl acetate (µg/L).

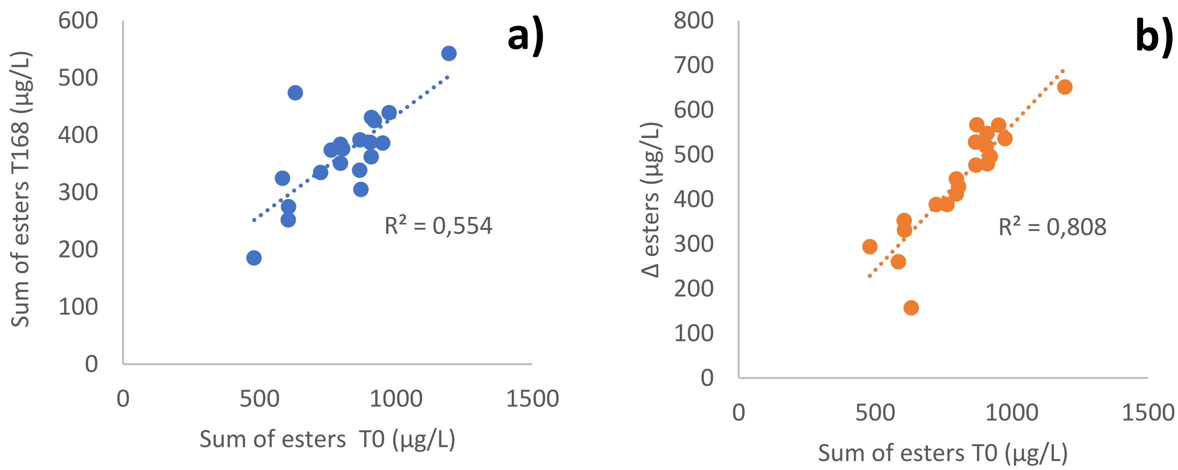


Figure 4.3.19. Correlation between sum of ethyl esters concentration in T0 wines (µg/L) and a) sum of ethyl esters concentration in T168 wines(µg/L) and b) Δ concentration (young wines- aged wines) of isoamyl acetate (µg/L).

4.4. Conclusion

- After aging treatment, the volatile metabolic profile of the studied wines underwent strong transformations. These transformations involved several classes of compounds of varietal and fermentative origin like esters, terpenes, norisoprenoids and to a lesser extent of some benzenoids.
- Despite these important differences, aged wines retained an aroma chemical signature that was characteristic of their geographical origin.
- Terpenes were important drivers of both aging and typicality. Their content drastically changed between young and aged wines. Some of them diminished until disappearing, such as geraniol, others instead appeared or increased, like cineoles. Occurence of these cineoles was linked to linalool content of the young wine
- Norisoprenoids such as TDN, TPB and vitispirane differentiated “young” from “aged” wines. The aging pattern of TPB and vitispirane highlighted varietal differences between Corvina and Corvinone wines, to be exploited during aging
- Most of the acetic and ethyl esters were found to decrease with aging in an amount correlated to their initial content. Branched chain ethyl esters increased with aging. Ester profile of aged wines was therefore partially correlated to the profile of young wines, suggesting a contribution of this compounds in the maintenance of aroma signatures. Although in part the fruity notes of acetic and ethyl esters were lost with aging, they were compensated by those of branched chain esters.

Concluding remarks

This thesis dealt with wine 'sense of place', aiming at identifying, measuring and then managing the components contributing to express the connection between a wine and its geographical origin, in particular through its aroma properties. Valpolicella red wines were used a model for this study, as they are characterized by unique grape varieties and a mix of conventional and peculiar winemaking practices such as post-harvest withering. A first central objective was therefore to investigate the existence of chemical markers that could be representative of different geographical origins (which in our case were different vineyard parcels), providing measurable components of a wine sense of place.

When wines form individual vineyards were compared within the same vintage, remarkable difference in aroma profiles were observed, highlighting the central importance of grape composition and origin in shaping wine aroma composition. Such diversity supports the hypothesis that individual geographical origins are able to generate wines with individual aroma identity, and should be considered an important *sine qua non* condition in the quest for wine sense of place. However, it is not sufficient in itself, as the fact that single vineyards wines differed among each other in every vintage does not imply a systematic nature of such differences, hence cannot be considered a proof of typicality. Our expectation about single vineyard wines identity and typicality was initially related to the possibility to define quantitative ranges of volatile markers that were characteristic of individual geographical origins, remaining relatively constant in all vintages. However, differences induced by vintage conditions on the absolute concentration of most aroma compounds, especially terpenes and norisoprenoids, were generally larger than those induced by geographical origin. Nevertheless, upon closer examination of the data obtained, a certain recurrence of target compounds with higher or lower contents on the same vineyards was observed. Accordingly, despite large vintage-related differences, the typicality associated with geographical origin was expressed through patterns of different volatile compounds that were maintained across the difference vintages. These patterns should be considered unique volatile chemical signatures of geographical origin, and allow associating wine aroma composition to the vineyard of grape origin. The provide therefore measurable markers of wine 'sense of place'. Terpenes and norisoprenoids, which were the compounds most affected by vintage, were also among the most important components of these unique aroma signatures, but several other compounds contributed to them. Among these, certain volatile compounds of fermentative origin, in particular acetate esters, were also strongly contributing to these aroma signatures. The expression of wine sense of place is therefore not exclusively mediated by (volatile) compounds that are directly linked to the grape, but also to the way in which grape composition determines specific metabolic responses of yeast. In an attempt to unravel the complexities of the relationship between grape compositional factors and wine aroma chemical signatures of geographical origin, some of the relationships between grape and wine composition were studied. It was found that higher/lower content of terpenes and norisoprenoid precursors in the grapes determines to a good extent wine content of these compounds. Conversely, wine content of acetate esters, in particular isoamyl acetate, is closely related to grape yeast assimilable nitrogen (YAN), which should be legitimately considered important modulator of a wine's ability to express its sense of place.

Interestingly, while in the absence of yeast grape-derived compounds (terpenes, norisoprenoids, benzenoids) could be associated with chemical signatures of geographical origin already at the level of grapes, it is with fermentation that most of these compounds attain concentrations of sensory relevance. Nevertheless, a series of experiments carried out with different yeasts and inoculation strategies showed that the different geographical origin of the grapes remained as the most potent driver of aroma diversity among the variables tested.

Likewise, model aging studies indicated that, despite showing significant quantitative differences their aroma composition compared to young wines, aged wines retained an aroma chemical signature characteristic of their geographical origin.

In conclusion, in the heterogeneity of Valpolicella wine styles, our results provide clear evidence for the existence, in the wines, of volatile chemical signatures that are representative of geographical origin. These chemical signatures can be considered measurable components of wine identity, typicality, and terroir. Factors that are central to the occurrence of variable levels of key signature compounds in relationship to vineyard of origin as well as to wine behaviour during aging were identified. Altogether, this work provides useful knowledge to support winemakers to manage wine production through appropriate vineyard and/or winemaking practices, in the quest of producing wines expressing their sense of place. In also paves the way for future investigation in the factors contributing to the expression of wine identity, typicality, and terroir.

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Appendix

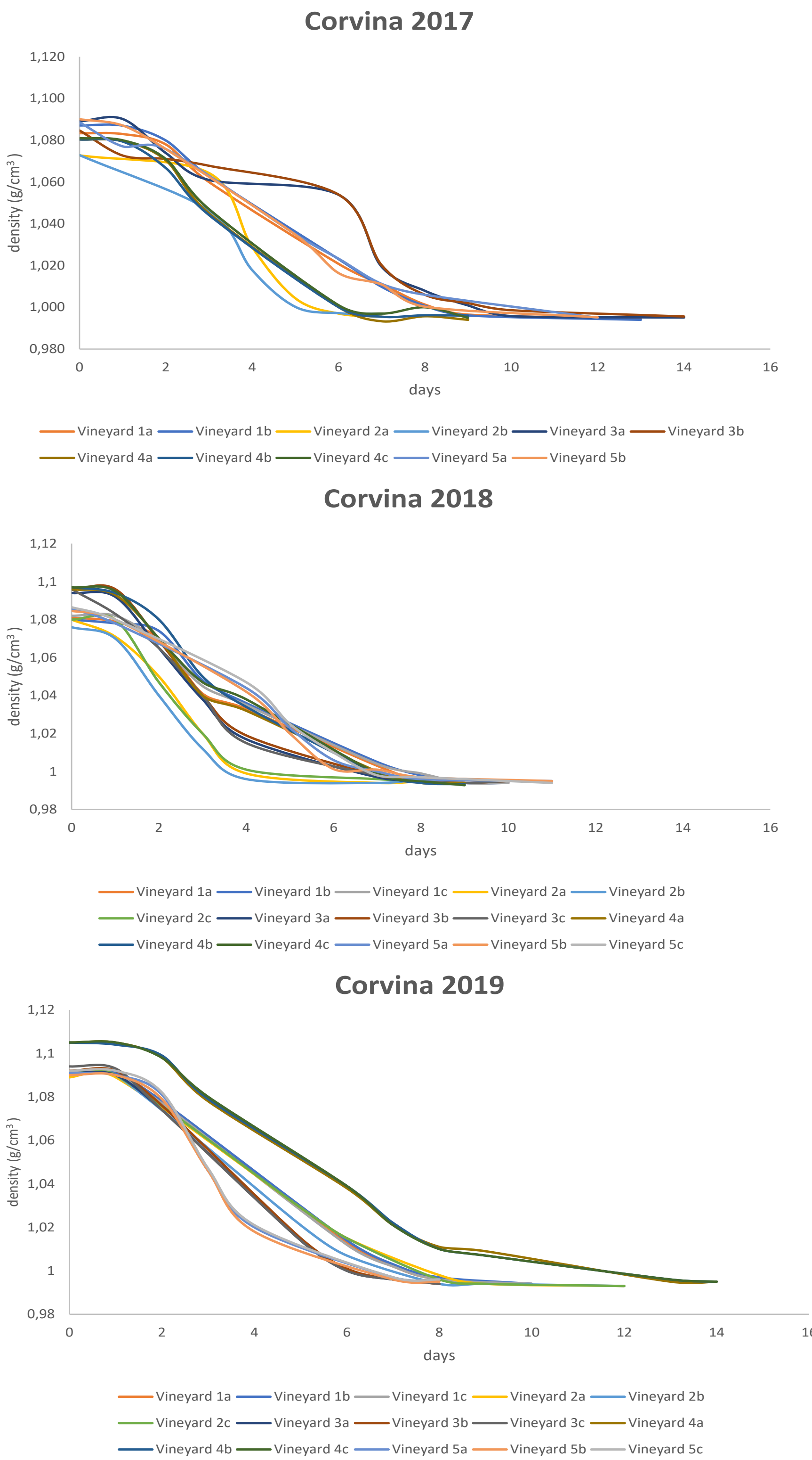
List of Appendix

Appendix 1.2.1. Minimum, mean and maximum temperature (ºC), expressed as monthly mean in the metereological station of Illasi and San Pietro

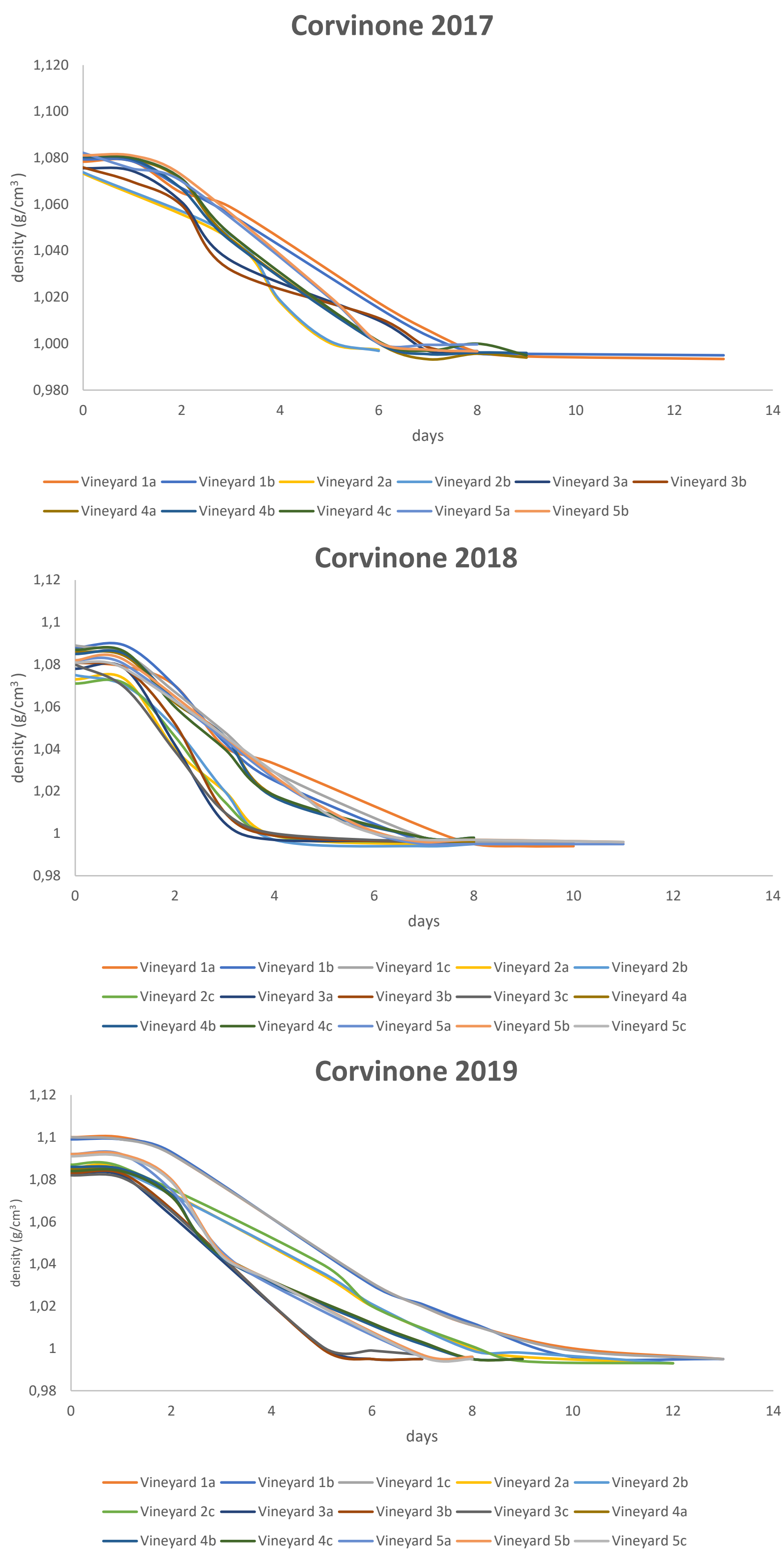
	Illasi			San Pietro		
	Min	**Mean**	**Max**	**Min**	**Mean**	**Max**
2016						
OCT	9.1	13.1	18.4	8.3	12.8	18
NOV	5.2	8.7	12.7	4.7	8.3	12.6
DEC	-0.9	3.5	8.8	-1.4	3	9.3
2017						
JAN	-3	1.2	6	-3.7	0.9	6.6
FEB	3.6	6.6	10.4	2.8	6.4	10.4
MAR	6.9	11.9	17.4	5.9	11.6	17.5
APR	9.2	14.1	19.2	8.7	14	19.3
MAY	13.1	18.3	24	12.2	18.1	23.9
JUN	17.6	24.1	30.2	17.1	23.9	30.3
JUL	18.2	24.6	30.8	17.5	24.5	31
AUG	19.5	25.8	32.6	18.6	25.5	32.1
SEP	12.8	17.4	23	12.4	17.3	22.9
OCT	9.4	13.9	20.1	8.2	13.6	20
NOV	4	7.7	12.2	3.3	7.3	12
DEC	-0.3	3.3	7.5	-1.4	2.6	7.6
2018						
JAN	2.7	6.1	9.9	1.7	5.4	9.9
FEB	1.2	3.8	7	0.2	3.3	6.8
MAR	4	7.2	10.8	3.2	6.8	10.8
APR	11.3	16.4	21.7	9.9	15.8	21.4
MAY	14.4	19.3	24.5	13.3	18.5	24.1
JUN	16.6	22.4	28.5	15.8	22.3	28.1
JUL	19	24.6	30.8	18	24.5	30.6
AUG	20	25.4	31.8	18.5	24.7	31
SEP	15.6	20.5	27.3	14.5	19.9	26.5
OCT	11.3	15.8	21.6	10	15.1	21.2
NOV	7.2	10.3	14.3	6.7	9.9	13.9
DEC	-0.4	3.5	8.1	-1.3	2.8	8.1
2019						
JAN	-1.1	2.7	7.2	-1.9	2.4	7.2
FEB	2.8	7.3	13	1.2	6.5	12.9
MAR	5	10.5	16.5	3.6	9.9	16.5
APR	9.4	13.5	17.8	8.7	13.4	18.2
MAY	10.8	14.7	19.1	10.4	14.7	19.2
JUN	19.2	25.6	31.5	18.2	25	31.1
JUL	19.2	25	31.2	18.8	25.1	31.1
AUG	19.1	24.9	31.4	18.8	24.6	30.8
SEP	14.7	19.6	25.8	14.1	19.3	25.4

Appendix 1.2.2. Sum of rains (mm), rainy days and humidity (%) minimum and maximum in the metereological station of Illasi and San Pietro

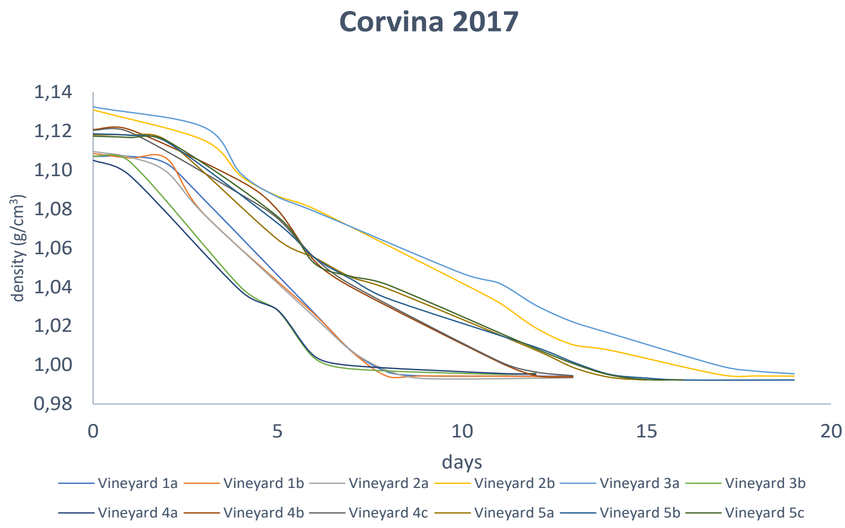
	Illasi						San Pietro					
	Rain		Min humidity		Max humidity		Rain		Min humidity		Max humidity	
	Sum (mm)	Days	Min	Max	Min	Max	Sum (mm)	Days	Min	Max	Min	Max
2016												
OCT	125.8	7	21	100	79	100	117.2	8	23	92	81	100
NOV	67.4	7	21	100	76	100	60.2	5	22	96	82	100
DEC	0.2	0	14	100	63	100	0.0	0	21	96	81	100
2017												
JAN	15.6	3	9	96	52	100	9.6	3	9	82	40	100
FEB	65.2	8	32	100	67	100	74.0	7	23	96	82	100
MAR	18.8	4	5	72	53	100	25.2	3	9	72	47	100
APR	46.4	7	9	82	53	100	79.8	7	9	79	40	100
MAY	76.2	11	29	71	70	100	88.4	14	26	70	73	100
JUN	60.8	6	27	55	73	100	39.0	6	25	54	71	100
JUL	37.6	6	28	50	65	100	49.8	5	16	49	61	100
AUG	16.6	4	26	50	65	100	24.4	2	26	45	66	100
SEP	108.0	12	27	84	80	100	95.2	13	18	68	63	100
OCT	33.8	3	22	83	77	100	24.8	2	16	80	76	100
NOV	88.4	6	23	92	79	100	70.8	8	22	100	70	100
DEC	47.2	5	29	96	70	100	45.4	5	20	94	72	100
2018												
JAN	33.4	2	20	94	78	100	33.2	4	18	100	77	100
FEB	42.6	8	18	99	52	100	25.2	8	29	100	56	100
MAR	103.8	16	29	98	63	100	93.2	16	27	100	67	100
APR	56.6	7	22	70	54	100	63.4	9	18	65	58	100
MAY	103.8	15	32	85	78	100	133.6	15	30	72	87	100
JUN	102.2	8	28	59	77	100	52.2	5	25	57	77	100
JUL	90.4	11	29	56	70	100	89.8	9	22	52	71	100
AUG	42.6	6	25	79	67	100	97.2	9	21	75	75	100
SEP	239.4	7	23	66	72	100	171.4	5	21	64	57	100
OCT	111.2	9	30	87	86	100	92.2	6	30	84	96	100
NOV	84.4	9	32	100	90	100	85.0	9	30	92	85	100
DEC	27.4	3	23	100	63	100	29.8	3	22	100	61	100
2019												
JAN	15.4	4	13	91	56	100	20.8	4	15	87	31	100
FEB	58.8	4	15	100	54	100	64.2	4	14	100	65	100
MAR	11.6	2	10	67	46	100	7.8	2	10	69	40	100
APR	101.2	12	24	97	58	100	109.8	10	21	65	53	100
MAY	245.0	16	34	88	78	100	179.6	17	27	86	79	100
JUN	11.6	1	21	55	53	100	5.0	2	15	50	67	100
JUL	103.8	10	32	83	73	100	77.8	6	27	65	72	100
AUG	52.8	4	29	52	79	100	83.2	7	32	57	81	100
SEP	85.2	6	27	98	78	100	106.8	5	25	100	79	100

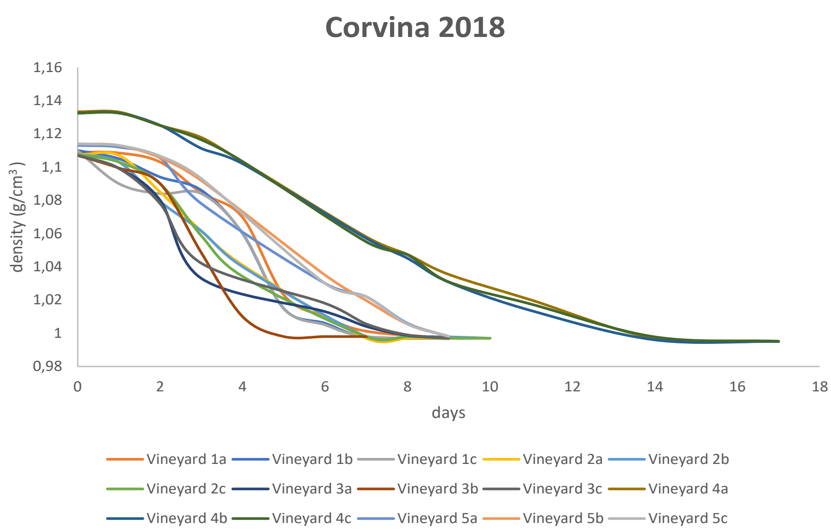


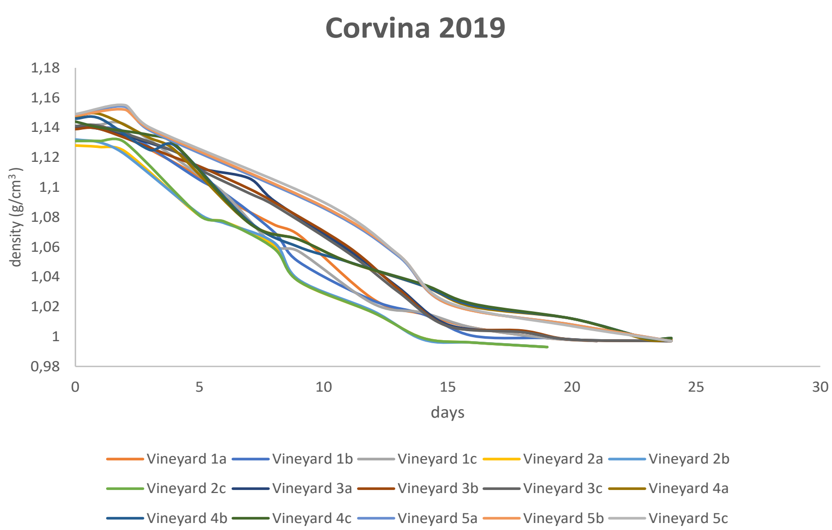
Appendix 1.2.3. Fermentation kinetics of fresh Corvina wines of 2017-2019 vintages. a, b and c refer to fermentation replicates



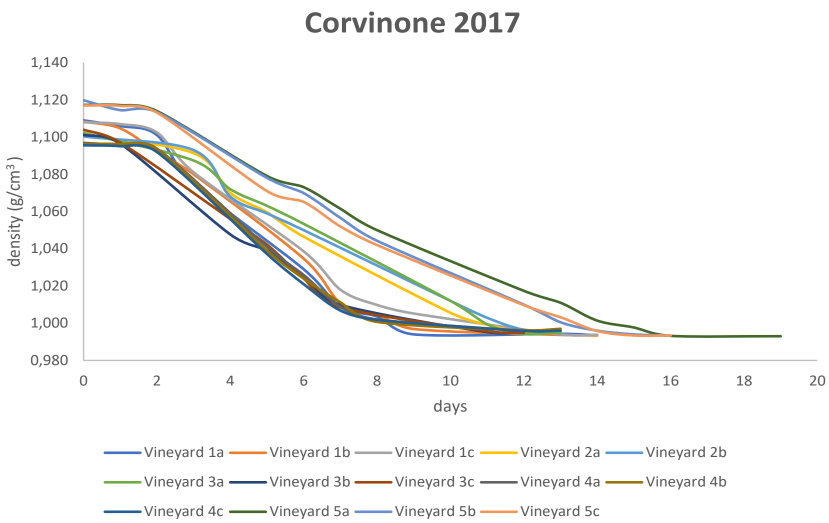
Appendix 1.2.4. Fermentation kinetics of fresh Corvinone wines of 2017-2019 vintages. a, b and c refer to fermentation replicates

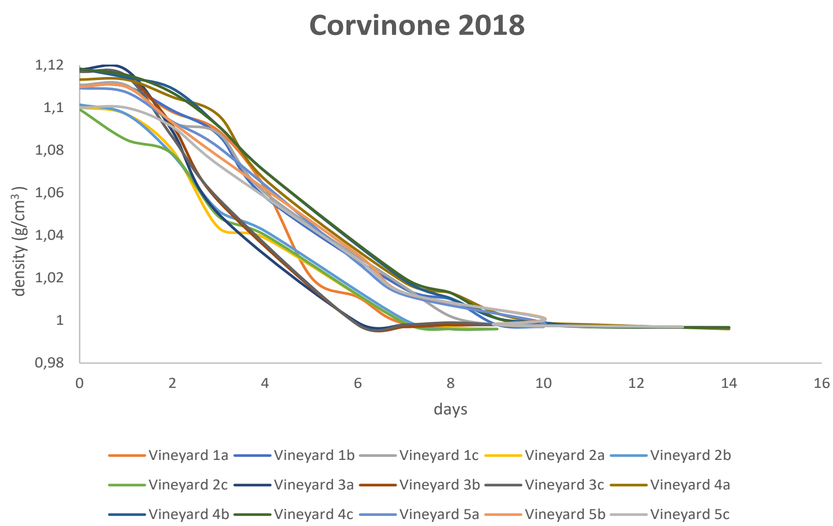


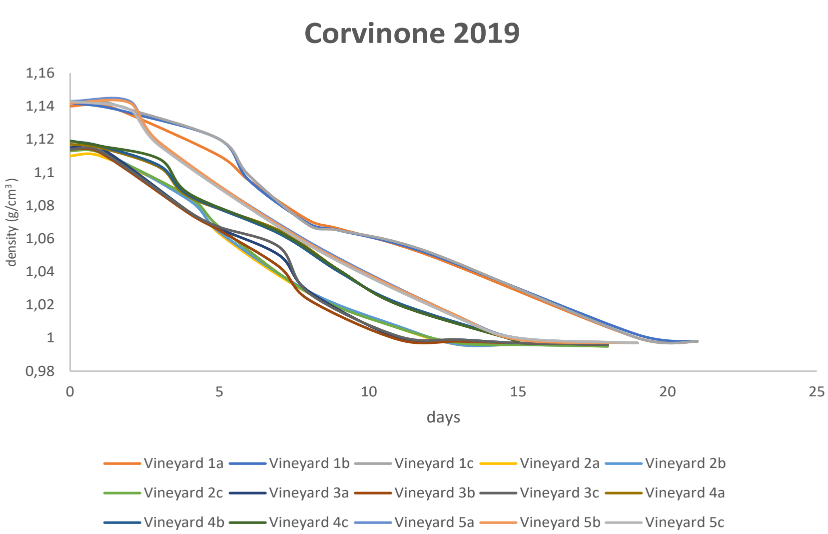




Appendix 1.2.5. Fermentation kinetics of withered Corvina wines of 2017-2019 vintages. a, b and c refer to fermentation replicates







Appendix 1.2.6. Fermentation kinetics of withered Corvina wines of 2017-2019 vintages. a, b and c refer to fermentation replicates

Appendix 1.2.7. Retention indices, quantification ions, LOD and LOQ of studied compounds

	EM[1]	LRI[2]	Identification[3]	Quantitation ion *m/z*	Qualifier ions *m/z*	LOD (μg/L)	LOQ (μg/L)
1-Butanol	a	1159	RS	56,00	55,00	0,02	0,06
2-Butanol	a	1020	RS	59,00		0,20	0,60
1-Pentanol	a	1256	RS	55,00	56, 57, 70	0,04	0,11
Isoamyl alcohol	a	1220	RS	57,00	55, 56, 70	0,02	0,06
Phenylethyl Alcohols	a	1920	RS	91,00	65, 92, 122	1,95	5,84
Methionol	a	1719	RS	106,00	57, 61, 73	0,06	0,17
1-Hexanol	a	1316	RS	56,00	55, 69	0,76	2,27
trans-3-Hexen-1-ol	a	1379	RS	67,00	55, 69, 82	0,40	1,21
cis-3-Hexen-1-ol	a	1391	RS	68,00	55, 69, 83	1,23	3,68
cis-2-Hexen-1-ol	a	1370	RS	57,00	57, 82	0,61	1,83
Isoamyl acetate	a	1125	RS	70,00	55, 60, 87	0,03	0,10
n-Hexyl acetate	a	1271	RS	56,00	55, 61, 84	0,03	0,10
2-Phenethyl acetate	a	1801	RS	104,00	91,00	0,04	0,13
Ethyl acetate	b	890	LRI MS	61,00	70, 88	-	-
Ethyl 2-methyl butanoate	a	1040	RS	102,00	74, 85, 115	0,02	0,07
Ethyl 3-methyl butanoate	a	1069	RS	88,00	57, 60, 85	0,30	0,90
Ethyl 3-hydroxybutanoate	a	1506	RS	117,00	71, 87	1,53	4,60
Ethyl di-2-hydroxyhexanoate	a	1540	LRI MS	87,00	69, 104	-	-
Ethyl butanoate	a	1032	RS	71,00	88,00	0,01	0,04
Ethyl hexanoate	a	1240	RS	88,00	60, 99	5,82	17,47
Ethyl octanoate	a	1430	RS	88,00	57, 100, 127	0,54	1,63
Ethyl decanoate	a	1640	RS	88,00	71, 101, 155	0,16	0,49
3-Methylbutanoic acid	a	1667	RS	60,00	87,00	0,17	0,52
Hexanoic acid	a	1839	RS	60,00	73, 87	0,15	0,46
Octanoic acid	a	2071	RS	60,00	73, 101, 115	0,00	0,01
cis-Linalooloxide	b	1437	RS	59,00	111, 94	0,02	0,07
trans-Linalooloxide	b	1469	RS	59,00	111, 94	0,02	0,07
Linalool	b	1547	RS	71,00	121, 93	0,08	0,25
Geraniol	b	1860	RS	93,00	123, 121, 105	0,06	0,20
β-Citronellol	b	1771	RS	69,00	82, 81, 67	0,07	0,21
α-Terpineol	b	1701	RS	136,00	121, 93, 59	0,23	0,70
α-Phellandrene	b	1180	RS	93,00	136, 91	0,11	0,34
α-Terpinen	b	1188	RS	121,00	93, 126	0,03	0,10
β-Myrcene	b	1161	RS	93,00	69, 79	0,41	1,06
Limonene	b	1198	RS	136,00	139, 125, 111	0,03	0,10
1,4-Cineole	b	1186	RS	154,00	139, 125, 111	0.003	0.01
1,8-Cineole	b	1217	RS	154,00	139, 111, 108	0,003	0,01
p-Cymene	b	1271	RS	119,00	134, 91	0,04	0,10
Terpinolene	b	1283	RS	121,00	136, 93	0,04	0,10
Terpinen-4-ol	b	1614	RS	71,00	111, 93, 86	0,02	0,05
Nerol	b	1812	RS	93,00	121, 84, 69	0,04	0,12
β-Damascenone	b	1825	RS	69,00	190, 121, 105	0,01	0,03
3-Oxo-α-ionol	a	2555	LRI MS	108,00	152,00	-	-
3-Hydroxy-β-damascone	a	2535	LRI MS	69,00	175, 193, 208	-	-
Vitispirane	b	1523	LRI MS	192,00	177, 93	-	-
TPB	b	1828	LRI MS	172,00	157, 142	-	-
TDN	b	1745	LRI MS	157,00	172, 142	-	-
Benzyl Alcohol	a	1874	RS	106,00	105, 77, 51	0,03	0,10
Vanillin	a	2572	RS	151,00	81, 152, 109	0,01	0,02
Vanillyl Alcohols	a	2762	RS	154,00	65, 93, 137	0,40	1,20
Ethyl vanillate	a	2665	RS	151,00	168, 196	2,36	7,09
Methyl vanillate	a	2630	RS	151,00	123, 182	0,97	2,91
Benzaldehyde	a	1538	RS	106,00	51, 77, 105	0,05	0,14
Eugenol	b	2172	RS	164,00	103, 149	0,07	0,22
Methyl salycilate	a	1771	RS	121,00	92, 152	0,00	0,00
γ-Decalactone	a	2141	RS	85,00	128,00	0,76	2,29
δ-decalactone	a	2193	RS	99,00	55, 71	0,74	2,23
2,6-Dimethoxyphenol	a	2270	RS	154,00	95, 111, 139	0,01	0,03
Furfural	a	1474	RS	96,00	95,00	0,15	0,45

Appendix 1.2.8. Performance report and LOD and LOQ of each employed kit on Y15 autosampler

Kit	Replicates	Standard Concentration	Mean concentration	SD	RSD	LOD	LOQ
PAN (mg/L)	10	70	71	2	2.8	1	3
	10	135	130	3	2.31		
Ammonia (mg/L)	10	50	52	3	5,8	3	8
	10	150	146	7	4,8		
Glucose + fructose (g/L)	10	1	1.03	0.04	3.9	0.1	0.3
	10	4	4.05	0.11	2.7		
Free SO2 (µg/L)	10	15	15.5	0.2	1.3	0.68	2.07
	10	77	76.1	0.7	1		
Acetic acid (g/L)	10	0.4	0.39	0.02	5	0,01	0,02
	10	0.8	0.82	0.03	3,7		

Appendix 1.3.1.1. Main enological parameters of grapes at crush

	PAN (mg/L)		Ammonia (mg/L)		YAN (mg/L)		Glucose + fructose (g/ L)		pH	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Corvina 2017										
Vineyard 1	49 fghi	1.4	29 jk	5.7	72.8 pqr	6.1	218.5 cde	1.4	2.93 lmn	0.02
Vineyard 2	105.5 ab	2.1	112.5 bc	2.1	198 abc	0.4	187.2 ijkl	12.4	3.32 a	0.01
Vineyard 3	43.5 hij	0.7	48 hij	0.0	83 mnopq	0.7	238.7 ab	5.3	3.04 hij	0.01
Vineyard 4	64.3 defg	5	58.7 gh	3.2	110.6 jkl	7.7	210.6 defg	3.5	3.12 defg	0.04
Vineyard 5	78 d	2.8	66.5 gh	0.7	132.7 fghij	3.4	224.2 bcd	5.3	2.99 ijkl	0.02
Corvina 2018										
Vineyard 1	55.7 efghi	0.6	35.3 jk	1.2	84.7 nopq	1.5	202 fghi	1.7	2.97 jkl	0.02
Vineyard 2	102.3 ab	8.7	130 ab	4.6	209.3 ab	12.5	183 jkl	4.4	3.10 efgh	0.01
Vineyard 3	105.7 ab	2.5	107.7 cd	3.8	194.2 bc	1.6	233.7 abc	4.0	3.03 ij	0.03
Vineyard 4	56.3 efgh	1.5	39.7 ij	2.5	89 mnop	3.2	213.7 def	2.5	3.18 cd	0.01
Vineyard 5	69.7 de	2.1	89 ef	3.6	158.142.9 fg	4.8	201.7 fghi	2.5	2.87 n	0.03
Corvina 2019										
Vineyard 1	28.7 j	11.5	34 jk	14.2	56.7 r	4.8	182.3 jkl	3.5	2.97 jklm	0.03
Vineyard 2	49.3 fghi	4.7	68 g	2.6	105 lmno	3.3	181 jklm	0.0	3.05 ghi	0.02
Vineyard 3	73.3 de	12.4	84 ef	3.2	142.5 ghij	10.6	221.6 cde	3.4	2.99 ijkl	0.02
Vineyard 4	45.9 ghij	5.1	20.8 k	2.1	63.1 r	5.2	249.7 a	3.5	3.21 bc	0.02
Vineyard 5	105.7 ab	2.9	112 c	2.0	197.7 cd	4.4	216.6 def	2.4	3.04 hi	0.02
Corvinone 2017										
Vineyard 1	37.5 hij	0.7	33.5 jk	2.1	65 qr	2.5	196 ghij	5.7	3.02 ijk	0.03
Vineyard 2	70.5 de	4.9	72 fg	1.4	129.7 ghij	3.8	195.2 ghij	3.9	3.18 cde	0.04
Vineyard 3	49 fghi	4.2	64.5 gh	2.1	102.1 klmn	2.5	196.7 ghij	0.4	3.07 fghi	0.05
Vineyard 4	77.3 d	4	58.3 gh	5.5	125.3 hijk	7.2	219. cde	8.4	3.27 ab	0.02
Vineyard 5	63.5 defg	2.1	60.5 gh	0.7	113.3 ijkl	1.5	206.5 efgh	4.2	3.12 defgh	0.00
Corvinone 2018										
Vineyard 1	65.7 def	8.4	90 e	1.0	139.7 fgh	8.4	238 ab	1.0	3.02 ij	0.02
Vineyard 2	81.3 cd	4.6	107 cd	9.2	169.4 de	11.4	165 m	5.6	3.15 cde	0.02
Vineyard 3	120.7 a	1.2	116.3 bc	0.6	216.4 a	1.0	194.3 hijk	4.0	3.14 cdef	0.02
Vineyard 4	54.7 efghi	1.5	59 gh	1.0	103.2 klm	2.2	178.3 klm	8.1	3.18 cd	0.02
Vineyard 5	104.3 ab	0.6	64.3 gh	1.5	157.3 ef	0.9	213 def	10.0	2.94 klm	0.02
Corvinone 2019										
Vineyard 1	37.7 ij	10.7	31.3 jk	2.8	62.8 r	8.5	202 fghi	1.0	2.9 mn	0.01
Vineyard 2	42.3 hij	1.5	37.3 ij	3.2	73 qr	2.6	176 lm	0.0	3.03 ij	0.01
Vineyard 3	70.5 de	7.2	94.4 de	12.2	148.1 fghi	15.8	187.1 ijkl	4.6	3.14 cdef	0.01
Vineyard 4	45.4 ghij	2.8	51.3 hi	3.5	87.5 opq	5.7	202.4 fghi	2.8	3.05 ghi	0.02
Vineyard 5	99.8 bc	5.4	139.7 a	3.2	214.7 bc	5.1	219.3 cde	3.1	3.01 ijk	0.01

Values in the same column with different letters indicate statistically significant differences (α=< 0.05) according to ANOVA.

Appendix 1.3.1.2. Enological parameters of fresh grapes musts at the end of alcoholic fermentation.

		Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
		mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Corvina 2017	Total acidity (g/L)	8.0	0.0	7.9	0.1	7.1	0.1	8.1	0.1	7.8	0.1
	pH	3.15	0.01	3.31	0.01	3.19	0.01	3.23	0.01	3.19	0.0
	Acetic acid (g/L)	0.18	0.01	0.15	0.01	0.31	0.01	0.39	0.02	0.23	0.0
	Ethanol (% v/v)	12.7	0.3	10.9	0.6	13.9	0.5	12.2	0.1	12.7	0.0
Corvina 2018	Total acidity (g/L)	8.4	0.2	7.3	0.4	9.0	0.1	8.2	0.1	8.8	0.3
	pH	3.22	0.03	2.88	0.01	2.96	0.02	3.25	0.02	2.77	0.0
	Acetic acid (g/L)	0.28	0.04	0.39	0.04	0.32	0.02	0.26	0.14	0.36	0.1
	Ethanol (% v/v)	11.7	0.2	10.7	0.3	13.5	0.4	12.3	0.1	11.7	0.1
Corvina 2019	Total acidity (g/L)	7.5	0.2	8.2	0.2	8.6	0.3	6.5	0.2	9.2	0.3
	pH	3.30	0.01	2.98	0.01	2.88	0.01	3.29	0.01	2.89	0.0
	Acetic acid (g/L)	0.25	0.07	0.29	0.08	0.17	0.04	0.32	0.05	0.32	0.1
	Ethanol (% v/v)	10.6	0.2	10.6	0.0	12.8	0.2	14.4	0.3	12.6	0.2
Corvinone 2017	Total acidity (g/L)	8.9	0.1	7.4	0.1	7.1		8.1	0.1	8.3	0.1
	pH	3.21	0.01	3.23	0.02	3.19	0.01	3.29	0.02	3.24	0.0
	Acetic acid (g/L)	0.23	0.01	0.15	0.03	0.19	0.00	0.25	0.12	0.10	0.0
	Ethanol (% v/v)	7.5	6.5	11.2	0.3	11.4	0.0	12.8	0.5	11.9	0.2
Corvinone 2018	Total acidity (g/L)	9.7	0.2	6.9	0.3	7.5	0.2	8.3	0.2	8.3	0.1
	pH	3.05	0.02	3.11	0.02	3.23	0.04	3.26	0.04	2.94	0.0
	Acetic acid (g/L)	0.28	0.02	0.24	0.03	0.31	0.01	0.32	0.06	0.24	0.0
	Ethanol (% v/v)	13.7	0.1	9.7	0.4	11.2	0.3	10.3	0.4	12.3	0.6
Corvinone 2019	Total acidity (g/L)	10.0	0.1	8.6	0.0	7.3	0.1	8.6	0.2	9.3	0.1
	pH	2.97	0.02	3.04	0.01	3.18	0.01	3.12	0.01	2.96	0.0
	Acetic acid (g/L)	<LOQ		0.18	0.04	0.13	0.05	0.17	0.04	0.29	0.0
	Ethanol (% v/v)	11.7	0.2	10.2	0.2	10.8	0.4	11.7	0.2	12.7	0.3

Appendix 1.3.1.3. Two-way ANOVA (α=0.05) of volatile compounds of fresh grapes wines according to different vineyards and vintages.

	Corvina						Corvinone					
	Vineyard		*Vintage*		*Vineyard*Vintage*		*Vineyard*		*Vintage*		*Vineyard*Vintage*	
	Pr > F	*Significant*	*Pr > F*	*Significant*	*Pr > F*	*Significant*	*Pr > F*	*Significant*	*Pr > F*	*Significant*	*Pr > F*	*Significant*
1-Butanol	0,841	No	<0.0001	Yes	0,00	Yes	0,672	No	<0.0001	Yes	<0.0001	Yes
Isoamyl alcohol	0,169	No	0,000	Yes	<0.0001	Yes	0,159	No	<0.0001	Yes	<0.0001	Yes
1-Pentanol	0,028	Yes	0,323	No	0,68	No	0,011	Yes	0,822	No	0,006	Yes
Phenylethyl alcohol	0,059	No	<0.0001	Yes	0,00	Yes	0,947	No	0,000	Yes	0,006	Yes
Methionol	0,009	Yes	<0.0001	Yes	0,00	Yes	0,143	No	<0.0001	Yes	<0.0001	Yes
1-Hexanol	0,008	Yes	0,009	Yes	<0.0001	Yes	0,021	Yes	0,041	Yes	<0.0001	Yes
trans-3-Hexen-1-ol	0,001	Yes	0,284	No	<0.0001	Yes	<0.0001	Yes	0,282	No	<0.0001	Yes
cis-3-Hexen-1-ol	0,279	No	<0.0001	Yes	<0.0001	Yes	0,074	No	0,003	Yes	<0.0001	Yes
cis-2-Hexen-1-ol	0,457	No	<0.0001	Yes	0,00	Yes	0,065	No	<0.0001	Yes	<0.0001	Yes
Isoamyl acetate	0,194	No	<0.0001	Yes	<0.0001	Yes	0,001	Yes	0,000	Yes	<0.0001	Yes
n-Hexyl acetate	0,037	Yes	0,020	Yes	<0.0001	Yes	0,008	Yes	0,110	No	<0.0001	Yes
2-Phenethyl acetate	0,001	Yes	0,030	Yes	<0.0001	Yes	<0.0001	Yes	0,199	No	<0.0001	Yes
Ethyl-2-methylbutanoate	0,016	Yes	<0.0001	Yes	<0.0001	Yes	0,012	Yes	<0.0001	Yes	<0.0001	Yes
Ethyl-3-methylbutanoate	0,013	Yes	<0.0001	Yes	<0.0001	Yes	0,050	No	<0.0001	Yes	<0.0001	Yes
Ethyl lactate	0,148	No	<0.0001	Yes	0,00	Yes	0,612	No	<0.0001	Yes	<0.0001	Yes
Ethyl butanoate	0,358	No	0,014	Yes	<0.0001	Yes	0,224	No	0,635	No	0,000	Yes
Ethyl 3-hydroxybutanoate	0,123	No	<0.0001	Yes	0,00	Yes	0,762	No	<0.0001	Yes	<0.0001	Yes
Ethyl hexanoate	0,487	No	<0.0001	Yes	<0.0001	Yes	0,521	No	<0.0001	Yes	<0.0001	Yes
Ethyl octanoate	0,794	No	<0.0001	Yes	<0.0001	Yes	0,214	No	<0.0001	Yes	<0.0001	Yes
Ethyl decanoate	0,978	No	<0.0001	Yes	<0.0001	Yes	0,213	No	<0.0001	Yes	<0.0001	Yes
Ethyl cinnamate	0,097	No	0,006	Yes	0,54	No	0,331	No	<0.0001	Yes	<0.0001	Yes
3-Methylbutanoic acid	0,002	Yes	0,000	Yes	0,00	Yes	<0.0001	Yes	0,060	No	<0.0001	Yes
Hexanoic acid	0,411	No	0,484	No	<0.0001	Yes	0,080	No	0,458	No	<0.0001	Yes
Octanoic acid	0,957	No	<0.0001	Yes	<0.0001	Yes	0,790	No	<0.0001	Yes	<0.0001	Yes
trans-Linaloloxide	0,662	No	0,002	Yes	0,18	No	0,906	No	<0.0001	Yes	0,063	No
cis-Linaloloxide	0,038	Yes	<0.0001	Yes	0,04	Yes	0,305	No	<0.0001	Yes	<0.0001	Yes
Linalool	0,078	No	<0.0001	Yes	<0.0001	Yes	0,001	Yes	0,000	Yes	<0.0001	Yes
α-Terpineol	0,039	Yes	<0.0001	Yes	<0.0001	Yes	<0.0001	Yes	0,000	Yes	<0.0001	Yes
β-Citronellol	0,005	Yes	<0.0001	Yes	0,00	Yes	0,049	Yes	<0.0001	Yes	<0.0001	Yes
Geraniol	0,000	Yes	0,017	Yes	0,00	Yes	0,014	Yes	0,000	Yes	<0.0001	Yes
α-Phellandrene	0,398	No	<0.0001	Yes	<0.0001	Yes	0,217	No	<0.0001	Yes	<0.0001	Yes
1,4-Cineol	0,416	No	<0.0001	Yes	<0.0001	Yes	0,165	No	<0.0001	Yes	<0.0001	Yes
Limonene	0,093	No	<0.0001	Yes	<0.0001	Yes	0,149	No	<0.0001	Yes	<0.0001	Yes
1,8-Cineol	0,003	Yes	<0.0001	Yes	<0.0001	Yes	0,005	Yes	0,220	No	<0.0001	Yes
p-Cymene	0,002	Yes	0,011	Yes	<0.0001	Yes	0,001	Yes	0,008	Yes	<0.0001	Yes
β-Damascenone	0,388	No	<0.0001	Yes	<0.0001	Yes	0,375	No	<0.0001	Yes	<0.0001	Yes
Vitispirane	0,001	Yes	<0.0001	Yes	<0.0001	Yes	0,048	Yes	<0.0001	Yes	<0.0001	Yes
TPB	0,341	No	<0.0001	Yes	<0.0001	Yes	0,502	No	<0.0001	Yes	<0.0001	Yes
TDN	0,319	No	<0.0001	Yes	<0.0001	Yes	0,400	No	<0.0001	Yes	<0.0001	Yes
Furfural	0,894	No	<0.0001	Yes	<0.0001	Yes	0,911	No	<0.0001	Yes	<0.0001	Yes
Benzaldehyde	0,968	No	<0.0001	Yes	<0.0001	Yes	0,999	No	<0.0001	Yes	<0.0001	Yes
Benzyl alcohol	0,006	Yes	0,001	Yes	<0.0001	Yes	0,084	No	<0.0001	Yes	<0.0001	Yes
Vanillin	0,001	Yes	0,006	Yes	0,00	Yes	0,941	No	<0.0001	Yes	0,000	Yes
Methyl-vanillate	0,000	Yes	0,215	No	<0.0001	Yes	0,000	Yes	0,000	Yes	<0.0001	Yes
Ethyl-vanillate	0,806	No	<0.0001	Yes	<0.0001	Yes	0,420	No	<0.0001	Yes	<0.0001	Yes
Methyl-salycilate	0,001	Yes	0,006	Yes	<0.0001	Yes	0,798	No	<0.0001	Yes	<0.0001	Yes
Eugenol	0,036	Yes	0,000	Yes	<0.0001	Yes	0,002	Yes	0,749	No	<0.0001	Yes
2,6-Dimethoxy-phenol	0,245	No	0,004	Yes	<0.0001	Yes	0,142	No	<0.0001	Yes	<0.0001	Yes
γ-Nonalactone	0,013	Yes	0,010	Yes	<0.0001	Yes	0,007	Yes	0,001	Yes	<0.0001	Yes

Appendix 1.3.1.4. Significantly different compounds and classes of compounds between Corvina and Corvinone in the three vintages (Mann-Whitney, α=0.05)

	2017	2018	2019
Alcohols	0.401	0.056	0.935
1-Butanol	0.606	0.412	0.319
Isoamyl alcohol	0.562	**0.045**	0.935
1-Pentanol	**0.000**	**0.002**	**0.015**
Phenylethyl alcohol	0.332	**0.045**	0.250
Methionol	0.478	0.713	0.174
C_6 Alcohols	0.217	0.595	0.217
1-Hexanol	**0.005**	0.285	**0.021**
trans-3-Hexen-1-ol	**<0.0001**	**0.000**	**<0.0001**
cis-3-Hexen-1-ol	**<0.0001**	**<0.0001**	**<0.0001**
cis-2-Hexen-1-ol	**0.003**	0.213	**0.037**
Acetate esters	0.365	0.056	0.412
Isoamyl acetate	0.401	0.061	0.436
2-Phenethyl acetate	0.217	**0.004**	0.539
n-Hexyl acetate	0.898	0.653	**0.015**
Ethyl esters	0.898	0.305	0.061
Ethyl lactate	**0.019**	0.713	0.217
Ethyl butanoate	0.438	0.106	**0.005**
Ethyl 3-hydroxybutanoate	0.056	0.775	0.744
Ethyl hexanoate	0.797	0.137	**0.045**
Ethyl octanoate	1.000	0.653	**0.019**
Ethyl decanoate	1.000	0.512	0.436
Ethyl cinnamate	**0.002**	0.633	0.198
Branched-chain fatty acid ethyl esters	**0.007**	**<0.0001**	**0.000**
Ethyl-2-methylbutanoate	**0.004**	**0.000**	**0.000**
Ethyl 3-methylbutanoate	**0.005**	**<0.0001**	**0.000**
Organic acid	0.748	0.595	0.806
3-Methylbutanoic acid	0.076	**0.007**	0.935
Hexanoic acid	0.652	0.775	0.713
Octanoic acid	0.949	0.567	0.806
Linear terpens	**<0.0001**	**<0.0001**	**<0.0001**
Linalool	**<0.0001**	**<0.0001**	**0.026**
β-Citronellol	0.467	**0.001**	**0.001**
Geraniol	**<0.0001**	**0.000**	**<0.0001**
Limonene	0.253	**0.001**	**0.041**
Nerol	0.373	**0.002**	**<0.0001**
Cyclic terpens	**<0.0001**	**0.000**	**0.037**
α-Terpineol	**<0.0001**	**0.018**	0.089
trans-Linaloloxide	**0.007**	0.372	0.464
cis-Linaloloxide	**0.007**	0.225	**0.002**
α-Phellandrene	0.584	**0.001**	**0.018**
α-Terpinen	**0.002**	**0.001**	**<0.0001**
1,4-Cineol	**<0.0001**	0.074	**<0.0001**
1,8-Cineol	**<0.0001**	**0.040**	**0.002**
p-Cymene	**0.001**	**<0.0001**	**0.025**
Terpinolene	0.343	**0.002**	**0.045**
p-Cymenene	**0.002**	**0.016**	**0.008**
Norisoprenoids	**0.001**	**0.001**	0.161
β-damascenone	**0.010**	**<0.0001**	0.443
3-hydroxy-β-damascone	**<0.0001**	0.066	**0.024**
Vitispirane	**<0.0001**	0.091	**0.018**
TPB	0.733	0.616	**<0.0001**
TDN	0.332	0.566	0.767
Benzenoids	**<0.0001**	**0.011**	**0.001**
Furfural	**0.042**	0.560	0.732
Benzaldehyde	0.411	**0.001**	**0.015**
Benzyl Alcohol	**<0.0001**	**<0.0001**	**<0.0001**
Vanillin	**0.002**	**0.004**	0.624
Methyl-vanillate	**0.003**	**<0.0001**	**<0.0001**
Ethyl-vanillate	**0.010**	**<0.0001**	**0.012**
Methyl-salycilate	0.097	0.350	0.467
Eugenol	**<0.0001**	**<0.0001**	**<0.0001**
2-6-Dimethoxy-phenol	0.171	0.362	0.098
Others	**0.001**	**0.001**	0.389
γ-Nonalactone	**0.001**	**0.001**	0.389

Appendix 1.3.1.5. Minimum (min) and Maximum (max) compounds content (µg/) in Corvina and Corvinone wines within the three vintages

	Corvina									Corvinone								
	2017			2018			2019			2017			2018			2019		
	Mean (µg/L)	Min (µg/L)	Max (µg/L)	Mean (µg/L)	Min (µg/L)	Max (µg/L)	Mean (µg/L)	Min (µg/L)	Max (µg/L)	Mean (µg/L)	Min (µg/L)	Max (µg/L)	Mean (µg/L)	Min (µg/L)	Max (µg/L)	Mean (µg/L)	Min (µg/L)	Max (µg/L)
Alcohols	323070.66	249764.10	391850.90	272748.58	223659.90	337816.70	259892.73	221434.50	329521.30	317833.71	254000.50	379955.80	249205.20	209715.20	285124.20	258852.62	219371.59	254000.50
1-Butanol	87.25	41.03	115.01	154.18	88.60	237.91	42.35	13.25	157.15	96.81	48.66	141.99	149.97	118.34	192.25	55.55	10.22	130.38
Isoamyl alcohol	302840.24	237382.20	372336.50	251710.28	208017.00	310136.00	247408.12	212462.90	302250.80	298009.46	239325.70	357681.70	230746.29	194834.00	264047.80	246418.63	206427.40	286309.60
1-Pentanol	57.90	46.89	73.74	57.47	38.25	80.61	66.92	47.54	159.22	84.62	58.68	104.55	79.61	52.70	103.53	82.08	51.65	152.32
Phenylethyl alcohol	19759.17	11813.61	24766.34	20406.95	15036.05	26846.12	12162.82	7735.26	26742.01	19304.56	14017.66	23051.70	17763.62	13865.47	20908.12	12142.63	8987.69	17868.97
Methionol	326.09	227.62	537.34	419.71	331.26	626.71	212.53	46.84	313.14	338.27	175.19	428.45	465.71	329.64	824.07	153.72	27.25	324.18
C6 alcohols	2269.38	1627.01	2764.38	1853.85	1126.25	2969.53	1322.26	786.99	2033.94	2067.76	1634.78	2433.04	1662.38	1016.64	2229.08	1581.90	661.07	1634.78
1-Hexanol	1559.46	1054.77	1996.25	1387.18	781.86	2367.98	1012.68	600.49	1703.39	1978.72	1562.21	2340.36	1580.14	958.91	2145.69	1509.57	629.17	2477.07
trans-3-Hexen-1-ol	9.28	6.53	13.22	9.55	5.63	16.69	7.81	4.70	12.47	19.03	15.24	25.86	18.76	8.64	28.94	23.80	7.36	47.37
cis-3-Hexen-1-ol	698.49	552.00	897.50	443.76	200.57	682.10	296.15	179.17	543.95	66.16	53.73	96.65	50.40	34.82	92.35	39.59	18.36	72.37
cis-2-Hexen-1-ol	2.15	0.65	4.90	13.35	12.61	14.00	5.62	2.22	18.35	3.85	2.59	5.47	13.08	11.79	14.32	8.93	3.00	19.50
Acetate esters	579.57	328.88	1089.88	1177.65	680.21	1695.59	644.20	457.44	849.70	506.39	312.12	974.31	922.54	521.44	1467.38	687.83	507.48	312.12
Isoamyl acetate	533.29	293.94	1011.92	1118.07	642.98	1601.01	601.78	424.21	796.80	467.39	273.48	929.09	877.97	492.66	1380.88	636.63	458.53	810.73
2-Phenethyl acetate	38.39	26.29	57.82	49.39	30.67	86.81	37.51	26.67	47.17	32.45	26.85	39.53	36.97	23.67	77.62	41.80	29.78	61.40
n-Hexyl acetate	7.90	3.59	20.14	10.18	4.31	22.62	4.92	2.02	8.77	6.55	3.35	9.81	7.61	5.10	10.63	9.40	2.69	18.45
Branched-chain fatty acids ethyl esters	23.68	12.28	35.45	10.63	8.36	12.29	17.40	10.24	23.69	15.03	10.83	22.34	7.95	6.83	9.86	11.62	9.80	10.83
Ethyl-2-methylbutanoate	11.72	6.23	17.67	5.44	4.30	6.34	8.68	5.31	11.82	7.58	4.89	11.40	4.21	3.66	5.05	5.98	4.91	8.20
Ethyl 3-methylbutanoate	11.96	5.69	17.78	5.19	3.93	6.49	8.71	4.91	11.87	7.45	5.04	10.94	3.74	3.11	4.91	5.65	4.60	7.61
Ethyl fatty acids esters	864.36	612.60	1323.67	1002.78	690.99	1360.88	1331.91	1130.82	1453.22	887.50	620.00	1316.38	903.58	740.91	1188.34	1248.53	944.64	620.00
Ethyl lactate	1692.39	1221.15	2395.33	710.69	314.78	1450.64	628.75	270.06	1072.32	1329.98	864.10	1879.48	635.69	542.87	764.20	504.27	323.27	707.61
Ethyl butanoate	137.50	96.94	211.37	149.07	113.99	197.64	168.36	151.50	183.65	134.65	93.42	219.26	132.81	107.34	176.17	145.03	15.87	173.87
Ethyl 3-hydroxybutanoate	182.76	142.33	227.00	229.61	156.69	304.66	295.22	204.48	352.96	208.12	157.48	244.10	232.31	193.37	370.60	304.39	221.42	356.71
Ethyl hexanoate	338.92	238.65	594.38	406.57	271.65	582.92	522.10	451.27	592.67	328.72	203.79	492.57	344.35	270.28	470.37	479.31	344.89	550.26
Ethyl octanoate	175.35	110.54	277.54	191.70	97.08	289.22	289.52	236.10	325.63	183.35	106.26	303.85	169.05	118.48	238.90	265.53	210.50	304.24
Ethyl decanoate	29.42	18.36	38.44	25.05	11.78	52.13	54.77	45.05	64.94	32.49	19.60	56.47	24.69	15.71	41.11	52.73	41.76	60.49
Ethyl cinnamate	0.42	0.07	0.81	0.79	0.02	6.45	1.95	0.02	4.17	0.17	0.06	0.38	0.37	0.02	2.75	1.54	0.77	2.85
Fatty acids	5134.94	3853.24	8307.27	7622.92	5683.90	9348.46	7434.57	6680.76	8457.99	4966.03	3567.55	7051.18	7461.07	6619.08	9276.98	7315.43	5348.20	3567.55
3-Methylbutanoic acid	452.91	300.67	581.94	507.91	382.08	673.41	358.16	232.12	455.29	388.12	333.46	480.13	416.34	325.64	562.82	354.73	234.40	443.00
Hexanoic acid	2638.72	1932.59	4491.63	2511.51	1264.07	3465.53	2337.56	1852.97	3060.67	2488.40	1789.91	3673.36	2472.34	1848.03	3591.17	2265.73	1374.86	2589.57
Octanoic acid	2043.30	1440.52	3373.26	4603.49	3579.74	5349.18	4738.85	4417.27	5038.26	2089.51	1439.60	3013.22	4572.39	3974.10	5374.47	4694.97	3660.57	5327.81
Terpenoids	73.33	54.16	98.31	43.55	38.25	48.58	54.54	28.14	79.32	32.73	21.99	41.93	24.80	19.76	29.65	29.69	22.70	21.99
trans-Linaloloxide	1.18	0.64	2.13	0.39	0.13	0.63	0.31	0.00	3.52	0.65	0.38	0.94	0.47	0.03	1.53	0.04	0.00	0.45
cis-Linaloloxide	1.12	0.55	2.17	0.33	0.02	0.96	1.06	0.37	2.13	0.65	0.33	1.05	0.13	0.02	0.79	0.58	0.00	0.97
Linalool	38.45	25.78	51.09	14.66	6.31	21.86	19.52	3.75	33.45	12.52	6.30	19.84	6.27	4.08	10.97	10.31	6.20	16.49
α-Terpineol	13.99	7.57	22.08	3.28	0.25	5.86	8.54	1.05	16.65	4.16	2.07	7.92	1.61	0.62	3.62	3.56	1.65	6.49
β-Citronellol	7.68	5.89	9.81	14.20	11.28	20.40	11.17	7.50	15.93	7.36	5.07	10.98	11.24	9.33	13.91	8.15	4.90	10.73
Geraniol	8.20	6.74	10.36	6.24	4.13	10.62	7.28	4.61	9.44	5.43	3.35	8.46	3.02	1.09	5.93	4.58	3.14	6.45
α-Phellandrene	0.34	0.04	0.64	1.52	0.32	2.51	0.82	0.10	1.65	0.30	0.20	0.55	0.66	0.41	1.13	0.26	0.12	0.44
α-Terpinen	0.08	0.02	0.12	0.09	0.03	0.15	0.00	0.00	0.00	0.04	0.02	0.06	0.04	0.02	0.13	0.00	0.00	0.02
1,4-Cineol	0.02	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Limonene	0.24	0.09	0.50	0.45	0.17	0.78	2.12	0.25	4.71	0.18	0.13	0.25	0.22	0.10	0.52	0.81	0.45	1.46
1,8-Cineol	0.02	0.01	0.04	0.01	0.00	0.02	0.03	0.01	0.04	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.02
p-Cymene	0.20	0.04	0.27	0.25	0.13	0.57	0.39	0.07	0.70	0.12	0.09	0.16	0.12	0.08	0.21	0.16	0.10	0.26
Terpinolene	0.17	0.03	0.26	0.48	0.12	0.80	1.46	0.13	3.36	0.14	0.07	0.28	0.21	0.09	0.62	0.50	0.20	1.05
Nerol	1.13	0.03	1.58	1.30	0.01	2.44	0.00	0.00	0.00	0.91	0.04	2.04	0.56	0.00	1.27	0.00	0.00	0.00
p-Cymenene	0.18	0.15	0.22	0.21	0.12	0.60	1.61	0.24	3.56	0.12	0.06	0.19	0.15	0.07	0.31	0.62	0.00	1.22
Norisoprenoids	19.79	9.21	24.65	5.72	1.02	22.94	5.18	1.91	10.14	32.47	20.37	43.44	8.72	2.96	29.03	6.32	2.33	20.37
β-Damascenone	4.83	0.14	9.61	1.32	0.44	1.95	3.50	1.38	6.05	8.26	4.17	11.06	2.51	1.52	3.18	3.96	1.05	5.99
3-Hydroxy-βa-damascone	0.00	0.00	0.00	0.10	0.05	0.16	0.10	0.07	0.13	0.00	0.00	0.00	0.08	0.04	0.10	0.09	0.06	0.19
Vitispirane	8.15	4.65	11.74	3.11	0.20	15.08	1.33	0.22	3.76	15.91	11.15	22.87	4.91	0.53	20.15	2.02	0.38	4.17
TPB	0.10	0.03	0.20	0.03	0.00	0.19	0.00	0.00	0.01	0.10	0.05	0.26	0.02	0.00	0.10	0.00	0.00	0.01
TDN	6.71	0.79	10.26	1.16	0.07	5.86	0.25	0.08	0.54	8.20	4.47	12.61	1.21	0.08	6.25	0.25	0.10	0.58
Benzenoids	159.10	135.25	183.21	236.62	172.22	304.52	276.64	238.16	337.72	122.57	103.29	143.02	198.04	173.61	237.45	226.02	162.96	103.29
Furfural	2.75	2.27	3.94	1.29	0.81	1.69	0.10	0.00	0.73	3.13	2.40	3.79	1.23	0.53	1.63	0.06	0.00	0.46
Benzaldehyde	15.10	14.56	16.13	15.35	14.74	16.30	4.21	1.28	8.55	14.92	14.56	15.26	14.75	14.25	16.35	2.36	1.26	4.90
Benzyl Alcohol	64.29	52.09	74.02	93.58	61.33	155.28	107.56	76.34	152.78	9.28	0.00	19.84	13.96	8.26	25.14	20.46	13.23	32.50
Vanillin	5.31	3.67	7.75	4.24	3.58	6.48	3.96	2.32	5.98	7.46	5.90	12.55	5.10	3.74	6.26	3.97	0.00	6.03
Methyl-vanillate	6.48	4.46	10.65	6.56	4.23	9.17	8.18	0.00	15.07	10.57	7.45	16.84	13.35	8.64	19.58	17.35	10.96	23.20
Ethyl-vanillate	57.25	35.17	71.65	101.67	72.09	116.29	139.23	120.25	159.46	71.15	50.17	83.29	139.05	120.11	178.07	169.73	120.44	220.12
Methyl-salycilate	0.11	0.04	0.21	0.93	0.00	2.30	0.70	0.12	2.04	0.07	0.02	0.14	0.47	0.30	0.93	0.65	0.39	1.13
2-6-Dimethoxyphenol	4.95	4.29	5.58	10.57	6.19	25.22	8.56	0.00	12.66	5.20	4.05	5.88	9.31	7.00	13.58	10.55	7.12	14.79
Eugenol	2.86	1.74	4.99	2.42	1.25	3.16	4.14	0.29	5.66	0.80	0.47	1.14	0.82	0.43	1.12	0.89	0.00	1.66
Others	10.66	6.35	15.28	10.59	7.37	12.93	14.06	10.06	23.29	17.09	12.07	20.48	12.55	10.79	14.68	14.77	11.37	12.07
γ-Nonalactone	10.66	6.35	15.28	10.59	7.37	12.93	14.06	10.06	23.29	17.09	12.07	20.48	12.55	10.79	14.68	14.77	11.37	21.65

Appendix 1.3.1.6. Odor Threshold (OT) and aromatic series of volatile compounds

Aromatic series	Compounds	OT (µg/L)
Vinous		
	1-Butanol	150000
	Isoamyl alcohol	30000
	1-Pentanol	64000
	Methionol	1000
	Isoamyl acetate	30
	n-Hexyl acetate	1500
	Ethyl lactate	154636
	Ethyl butanoate	20
	Ethyl-2-methylbutanoate	18
	Ethyl-3-methylbutanoate	3
	Ethyl-3-hydroxybutanoate	20000
	Ethyl hexanoate	5
	Ethyl octanoate	14
	Ethyl decanoate	200
	3-Methylbutanoic acid	250
	Hexanoic acid	420
	Octanoic acid	500
Fruity		
	Isoamyl acetate	30
	n-Hexyl acetate	1500
	Ethyl lactate	154636
	Ethyl butanoate	20
	Ethyl-2-methylbutanoate	18
	Ethyl-3-methylbutanoate	3
	Ethyl-3-hydroxybutanoate	20000
	Ethyl hexanoate	5
	Ethyl octanoate	14
	Ethyl decanoate	200
	β-damascenone	0.05
	γ-nonalactone	30
Red fruit	Ethyl-2-methylbutanoate	18
	Ethyl-3-methylbutanoate	3
Floral	Phenylethyl alcohol	14000
	2-Phenethyl acetate	250
	Ethyl cinnamate	1.1
	trans-Linaloloxide	3000
	cis-Linaloloxide	3000
	Linalool	25
	α-Terpineol	250
	β-Citronellol	100
	Geraniol	20
	α-Phellandrene	40
	Limonene	200
	p-Cymene	11
	Nerol	300
	Methyl-salycilate	40
Green	1-Hexanol	8000
	trans-3-Hexen-1-ol	1000
	cis-3-Hexen-1-ol	400
	cis-2-Hexen-1-ol	100
	Isoamyl alcohol	30000
Spicy		
	Ethyl cinnamate	1.1
	Vitispirane	800
	Furfural	14100
	Benzaldehyde	3000
	Benzyl Alcohol	200000
	Vanillin	200
	Methyl-vanillate	3000
	Ethyl-vanillate	990
	Eugenol	6
	2-6-Dimethoxy-phenol	570
Balsamic		
	α-Terpineol	250
	α-Phellandrene	40
	1,4-Cineol	0.63
	1,8-Cineol	1.3
	Vitispirane	800
	Methyl-salycilate	40
Tobacco-evolutive		
	β-Damascenone	0.05
	TPB	0.04
	TDN	2

Appendix 1.3.1.7. OAVs of aroma active compounds in single vineyards wines

	2017					2018					2019				
	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
Corvina															
β-damascenone	78,10	187,40	94,00	102,67	62,90	37,47	27,07	22,13	10,13	34,93	41,67	74,27	91,87	31,47	111,00
Ethyl hexanoate	52,32	48,00	57,12	68,03	113,32	96,94	75,50	111,25	65,63	57,25	100,75	114,25	107,06	93,42	106,62
Ethyl 3-hydroxybutanoate	11,51	13,50	12,21	12,85	15,30	17,54	18,54	19,09	13,42	13,41	18,50	22,13	24,66	16,83	23,33
Isoamyl acetate	9,97	13,79	10,66	21,25	31,48	23,83	36,11	49,14	49,44	27,83	15,67	21,10	24,02	18,63	20,88
Isoamyl alcohol	9,84	8,03	10,75	9,78	12,22	7,94	7,44	8,26	9,97	8,35	8,75	8,45	7,88	8,93	7,22
Ethyl octanoate	9,18	10,05	9,79	13,96	18,93	19,57	11,63	18,57	9,54	9,14	18,38	22,15	22,22	20,77	19,90
Ethyl butanoate	5,10	5,69	6,20	7,10	10,17	7,50	7,17	9,76	6,98	5,87	8,11	9,06	8,51	7,78	8,63
Hexanoic acid	4,76	4,86	5,12	6,70	9,76	6,99	6,56	7,96	4,10	4,29	4,82	6,96	5,62	4,70	5,73
Ethyl 3-methylbutanoate	4,41	1,99	5,49	3,74	4,42	1,93	1,32	1,93	1,80	1,68	3,17	1,65	3,94	2,75	3,02
Octanoic acid	3,38	3,41	2,99	4,35	6,17	10,10	9,60	10,33	8,63	7,37	9,08	10,04	9,72	9,13	9,41
Linalool	1,89	1,62	1,34	1,08	1,98	0,26	0,49	0,66	0,66	0,86	0,18	1,08	0,90	0,45	1,30
cis-3-Hexen-1-ol	1,79	1,73	1,68	1,44	2,24	1,13	1,63	1,39	0,85	0,54	0,66	1,15	0,60	0,52	0,78
3-Methylbutanoic acid	1,74	1,23	2,19	2,02	1,78	2,39	1,57	2,11	2,39	1,71	1,79	1,38	1,31	1,69	1,01
Phenylethyl alcohol	1,71	0,90	1,51	1,45	1,47	1,37	1,17	1,38	1,84	1,53	1,43	0,76	0,66	0,88	0,63
TDN	1,50	3,12	5,03	3,07	4,20	0,04	0,06	0,12	0,05	2,65	0,05	0,18	0,20	0,05	0,16
TPB	1,25	3,50	4,13	2,25	2,13	0,17	0,25	0,25	0,00	3,42	0,00	0,00	0,17	0,00	0,08
Corvinone															
β-damascenone	87,00	213,20	217,30	145,40	172,50	62,80	60,73	46,33	31,47	49,53	27,73	58,27	104,27	117,27	88,27
Ethyl hexanoate	50,08	42,16	60,92	95,00	65,92	85,83	60,68	80,82	56,43	60,59	79,01	97,54	94,67	107,33	100,76
Ethyl 3-hydroxybutanoate	11,66	13,17	16,23	16,62	15,76	21,90	14,15	16,59	15,52	14,80	17,69	20,69	22,77	22,93	24,63
Isoamyl acetate	9,47	11,87	9,88	28,25	12,10	27,25	27,75	29,72	44,05	17,56	16,33	18,93	19,65	26,80	24,40
Isoamyl alcohol	9,20	8,40	10,33	10,09	11,57	8,13	7,44	6,73	8,61	7,56	7,90	9,04	7,27	9,36	7,50
Ethyl octanoate	8,95	8,29	12,57	20,46	11,53	14,70	11,42	14,10	10,43	9,73	16,22	18,31	20,46	21,34	18,50
Ethyl butanoate	4,85	5,01	5,90	10,43	5,62	7,97	6,19	7,99	5,54	5,52	6,43	7,78	5,50	8,55	8,00
Hexanoic acid	4,76	4,33	5,58	8,52	5,14	6,26	5,51	7,68	4,50	5,48	3,85	5,84	5,85	5,59	5,85
Ethyl 3-methylbutanoate	3,30	1,97	2,77	2,18	2,35	1,62	1,17	1,08	1,18	1,19	2,49	1,58	1,91	1,67	1,76
Octanoic acid	3,04	2,96	4,31	5,77	4,02	9,52	9,01	10,31	8,59	8,29	8,00	9,27	10,13	10,37	9,19
TDN	2,38	4,13	6,17	2,81	5,66	0,05	0,05	0,04	0,26	2,62	0,08	0,11	0,08	0,11	0,25
3-Methylbutanoic acid	1,67	1,34	1,66	1,63	1,41	1,88	1,53	1,41	2,12	1,38	1,38	1,68	1,33	1,71	0,99
Phenylethyl alcohol	1,48	1,01	1,43	1,44	1,50	1,28	1,32	1,04	1,47	1,24	0,82	0,80	0,92	1,10	0,70
TPB	1,25	2,38	2,63	3,33	2,38	0,25	0,00	0,00	0,33	2,00	0,00	0,00	0,00	0,00	0,17
cis-3-Hexen-1-ol	0,24	0,14	0,14	0,16	0,15	0,22	0,12	0,09	0,09	0,10	0,05	0,16	0,06	0,11	0,12

Appendix 1.3.1.8. Concentration (μg/L) and standard deviation (± μg/L) of volatile compounds of 2017 Corvina wines

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	48.45	7.42	109.09	5.23	89.27	4.05	100.69	11.45	86.10	12.32
Isoamyl alcohol	295219.36	16079.20	240802.42	3420.25	329794.74	7158.00	293498.80	15062.36	366714.59	5621.95
1-Pentanol	46.93	0.04	71.68	2.07	51.16	1.14	55.42	3.71	64.41	3.44
Phenylethyl alcohol	23897.15	869.19	12592.91	779.30	21668.54	533.40	20324.64	861.59	20563.30	1488.41
Methionol	237.60	2.99	362.08	18.14	264.52	18.45	449.47	73.94	273.57	6.56
C_6 alcohols										
1-Hexanol	1795.83	200.42	1690.79	2.62	1584.96	32.03	1088.84	25.42	1840.19	9.12
trans-3-Hexen-1-ol	9.30	0.06	10.05	0.47	9.67	0.46	6.66	0.13	12.48	0.75
cis-3-Hexen-1-ol	715.94	39.28	692.95	10.73	659.67	12.34	577.26	27.02	894.90	2.60
cis-2-Hexen-1-ol	2.09	0.07	1.84	0.28	1.65	0.12	1.01	0.26	4.63	0.27
Acetate esters										
Isoamyl acetate	299.22	5.28	413.59	17.37	321.61	1.92	637.56	30.19	944.25	67.67
2-Phenethyl acetate	33.22	2.32	26.45	0.16	35.49	0.93	40.15	0.78	56.69	1.14
n-Hexyl acetate	4.07	0.03	7.27	0.32	3.59	0.74	6.17	0.72	18.51	1.64
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	12.69	0.99	6.41	0.18	17.67	0.93	11.57	1.60	11.29	0.36
Ethyl 3-methylbutanoate	13.23	0.25	5.98	0.29	17.78	1.33	11.23	1.22	13.27	0.88
Ethyl fatty acids esters										
Ethyl lactate	1442.22	221.06	2106.21	289.12	1702.49	6.02	1509.52	158.46	1786.91	37.75
Ethyl butanoate	102.04	5.10	113.80	3.83	127.40	3.44	142.10	6.92	203.31	8.07
Ethyl 3-hydroxybutanoate	161.14	18.81	189.06	4.01	176.35	5.47	179.94	10.97	214.20	12.80
Ethyl hexanoate	261.60	17.98	240.02	1.37	282.80	2.78	340.17	8.90	566.59	27.79
Ethyl octanoate	128.53	17.99	140.66	0.49	128.43	8.61	195.46	2.34	265.01	12.54
Ethyl decanoate	20.48	2.12	33.60	0.98	20.63	1.12	32.61	2.53	37.06	1.38
Ethyl cinnamate	0.78	0.03	0.31	0.05	0.37	0.01	0.24	0.13	0.49	0.05
Fatty acids										
3-Methylbutanoic acid	434.30	18.83	306.32	5.65	581.94	34.56	505.41	51.22	444.90	2.52
Hexanoic acid	1998.23	65.64	2042.37	45.17	2175.43	23.02	2814.31	34.58	4098.50	393.13
Octanoic acid	1689.53	184.34	1706.79	29.46	1440.52	54.43	2173.23	56.58	3087.07	286.20
Terpenoids										
cis-Linaloloxide	1.54	0.10	0.87	0.06	0.97	0.13	0.79	0.15	2.08	0.05
trans-Linaloloxide	1.15	0.20	1.07	0.03	0.96	0.17	0.64	0.09	1.84	0.34
Linalool	47.25	1.91	40.61	0.93	34.15	0.56	27.02	0.97	49.47	1.62
Terpinen-4-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
α-Terpineol	17.24	0.62	15.21	0.19	11.42	0.15	8.78	0.93	20.07	2.01
β-Citronellol	8.58	0.30	7.43	0.61	6.25	0.18	8.79	0.74	6.97	0.76
Geraniol	9.07	0.28	8.11	0.93	7.38	0.32	7.84	0.50	9.09	1.27

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
α-Phellandrene	0.09	0.06	0.59	0.08	0.24	0.15	0.39	0.03	0.38	0.04
α-Terpinen	0.05	0.04	0.11	0.02	0.07	0.03	0.09	0.00	0.06	0.00
1,4-Cineol	0.02	0.01	0.01	0.00	0.02	0.00	0.01	0.00	0.02	0.00
Limonene	0.15	0.08	0.46	0.06	0.16	0.05	0.24	0.01	0.22	0.04
1,8-Cineol	0.02	0.01	0.02	0.00	0.02	0.00	0.02	0.00	0.03	0.01
p-Cymene	0.14	0.13	0.25	0.04	0.19	0.06	0.21	0.02	0.20	0.03
Terpinolene	0.09	0.08	0.26	0.00	0.12	0.06	0.22	0.01	0.16	0.03
Nerol	0.52	0.69	0.95	0.07	1.21	0.01	1.44	0.08	1.41	0.25
p-Cymenene	0.15	0.00	0.20	0.01	0.17	0.01	0.19	0.03	0.17	0.19
Norisoprenoids										
β-Damascenone	3.91	0.17	9.37	0.24	4.70	0.03	5.13	0.14	3.15	0.14
3-Hydroxy-β-damascone	0.12	0.01	0.11	0.01	0.09	0.01	0.07	0.01	0.09	0.01
Vitispirane	5.28	0.88	7.22	0.75	9.42	0.71	7.59	0.25	11.55	0.27
TPB	0.05	0.03	0.14	0.01	0.17	0.05	0.09	0.00	0.09	0.01
TDN	2.99	3.11	6.23	0.78	10.06	0.29	6.14	0.25	8.40	0.05
Benzenoids and others										
Furfural	2.40	0.06	3.16	0.11	2.27	0.00	3.32	0.44	2.33	0.01
Benzaldehyde	15.21	0.24	15.75	0.39	15.25	0.05	14.71	0.14	14.85	0.00
Benzyl Alcohol	68.01	2.06	65.06	8.96	56.63	2.27	69.70	3.63	61.61	3.50
Vanillin	7.15	0.61	4.49	0.02	6.73	0.74	5.10	0.32	3.92	0.25
Methyl-vanillate	7.86	0.59	4.50	0.04	4.84	0.06	5.28	0.08	10.44	0.22
Ethyl-vanillate	63.25	8.40	66.57	2.09	70.52	2.29	36.39	0.97	62.27	1.68
Methyl-salycilate	<LOQ		<LOQ		<LOQ		<LOQ		<LOQ	
2-6-Dimethoxyphenol	4.86	0.07	4.87	0.07	5.55	0.02	5.08	0.39	4.33	0.04
Eugenol	3.45	0.28	4.81	0.19	2.37	0.01	1.92	0.21	2.27	0.27
γ-Nonalactone	12.12	1.75	13.83	0.49	15.28	4.38	8.54	1.56	8.94	2.40

Appendix 1.3.1.9. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2018 Corvina wines

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	90.48	2.95	200.62	32.38	148.01	15.69	163.09	0.71	168.69	22.55
Isoamyl alcohol	238088.80	3883.95	223193.29	13611.46	247680.46	23326.92	299202.68	9484.58	250386.18	14720.92
1-Pentanol	52.21	1.67	76.10	4.82	62.03	2.04	40.81	4.12	56.20	1.17
Phenylethyl alcohol	19209.10	1733.84	16347.93	1396.26	19349.89	2541.85	25774.07	991.07	21353.73	1297.24
Methionol	372.21	23.97	390.27	58.72	358.16	27.98	585.13	39.04	392.78	44.32
C_6 alcohols										
1-Hexanol	1092.45	6.63	1743.51	109.29	2320.74	66.13	802.69	21.73	976.53	70.76
trans-3-Hexen-1-ol	6.74	0.21	12.32	0.79	16.18	0.44	5.74	0.16	6.78	0.18
cis-3-Hexen-1-ol	452.38	7.91	651.48	35.53	557.54	16.51	341.27	14.27	216.12	13.48
cis-2-Hexen-1-ol	13.61	0.28	13.85	0.22	12.69	0.09	13.01	0.11	13.60	0.44
Acetate esters										
Isoamyl acetate	714.83	66.88	1083.31	140.17	1474.30	21.18	1483.18	102.39	834.75	60.82
2-Phenethyl acetate	32.86	0.98	36.54	6.07	53.69	1.14	81.36	5.59	42.51	2.49
n-Hexyl acetate	4.75	0.57	12.42	0.68	21.04	1.37	7.69	0.17	4.99	0.41
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	4.91	0.56	4.44	0.09	5.87	0.06	5.99	0.44	5.99	0.41
Ethyl 3-methylbutanoate	5.79	0.56	3.96	0.04	5.79	0.63	5.41	0.06	5.03	0.29
Ethyl fatty acids esters										
Ethyl lactate	344.63	32.03	1227.22	203.81	749.75	39.13	493.87	64.71	737.96	136.92
Ethyl butanoate	150.01	13.50	143.34	1.81	195.13	3.02	139.56	19.67	117.30	2.96
Ethyl 3-hydroxybutanoate	245.57	24.41	259.61	39.18	267.32	29.51	187.82	9.69	187.72	39.22
Ethyl hexanoate	484.72	24.07	377.51	12.37	556.25	34.75	328.13	39.70	286.24	20.44
Ethyl octanoate	274.02	20.05	162.86	8.45	260.01	22.07	133.60	32.07	128.02	1.64
Ethyl decanoate	45.76	5.58	16.38	0.50	29.39	2.65	18.06	5.44	15.64	0.96
Ethyl cinnamate	0.42	0.09	0.18	0.06	0.09	0.09	0.10	0.07	0.21	0.14
Fatty acids										
3-Methylbutanoic acid	596.36	67.04	391.73	11.11	526.85	11.06	596.75	99.43	427.85	26.20
Hexanoic acid	2935.73	277.58	2753.72	117.91	3344.69	141.06	1722.61	397.93	1800.83	178.05
Octanoic acid	5049.38	160.04	4802.22	150.67	5163.71	179.82	4316.41	302.45	3685.75	183.33
Terpenoids										

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
cis-Linaloloxide	0.26	0.22	0.39	0.03	0.44	0.12	0.36	0.09	0.48	0.27
trans-Linaloloxide	0.14	0.18	0.77	0.19	0.45	0.38	0.06	0.04	0.25	0.34
Linalool	6.56	0.23	12.31	0.93	16.52	0.30	16.45	0.38	21.48	0.43
Terpinen-4-ol	0	0	0	0	0	0	0	0	0	0
α-Terpineol	0.29	0.05	3.69	0.21	3.17	0.20	3.56	0.13	5.70	0.18
β-Citronellol	19.33	1.69	13.07	0.22	11.61	0.41	15.20	0.06	11.80	0.32
Geraniol	10.20	0.50	4.57	0.27	5.25	0.07	6.69	0.18	4.52	0.36
α-Phellandrene	1.26	0.13	1.65	0.07	1.95	0.33	2.29	0.24	0.38	0.05
α-Terpinen	0.03	0.00	0.08	0.01	0.13	0.02	0.10	0.01	0.14	0.01
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Limonene	0.20	0.02	0.37	0.05	0.56	0.08	0.65	0.04	0.31	0.01
1,8-Cineol	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.02	0.00
p-Cymene	0.20	0.03	0.20	0.01	0.24	0.02	0.21	0.02	0.41	0.06
Terpinolene	0.12	0.00	0.46	0.06	0.72	0.05	0.74	0.10	0.26	0.05
Nerol	2.16	0.25	1.23	0.15	1.32	0.21	1.74	0.08	0.02	0.00
p-Cymenene	0.13	0.01	0.19	0.02	0.22	0.01	0.18	0.03	0.33	0.24
Norisoprenoids										
β-Damascenone	1.87	0.07	1.35	0.06	1.11	0.04	0.51	0.06	1.75	0.04
3-Hydroxy-βa-damascone	0.15	0.02	0.10	0.01	0.11	0.02	0.05	0.01	0.08	0.01
Vitispirane	0.22	0.02	0.56	0.06	1.19	0.14	0.46	0.01	13.10	1.74
TPB	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.14	0.05
TDN	0.08	0.01	0.12	0.01	0.23	0.03	0.09	0.01	5.29	0.70
Benzenoids and others										
Furfural	1.67	0.03	1.27	0.04	1.61	0.07	1.07	0.13	0.85	0.04
Benzaldehyde	15.37	0.13	15.89	0.44	15.08	0.21	14.94	0.21	15.48	0.47
Benzyl Alcohol	150.98	4.35	66.22	5.64	108.87	2.94	79.27	1.25	62.58	0.70
Vanillin	5.82	0.58	3.81	0.31	3.78	0.16	3.78	0.21	4.03	0.47
Methyl-vanillate	4.25	0.03	5.67	0.27	6.75	0.10	7.39	0.40	8.74	0.38
Ethyl-vanillate	97.66	5.32	75.24	2.73	109.93	2.25	113.99	2.59	111.53	2.46
Methyl-salycilate	0.13	0.02	0.22	0.19	0.91	0.02	2.24	0.08	1.15	0.79
2-6-Dimethoxyphenol	21.43	3.29	8.99	0.53	6.49	0.27	7.79	1.12	8.16	0.56
Eugenol	2.31	0.02	3.11	0.05	3.02	0.01	2.35	0.10	1.31	0.06
γ-Nonalactone	11.17	0.62	9.72	0.22	11.23	0.24	8.39	0.89	12.45	0.47

Appendix 1.3.1.10. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2019 Corvina wines

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	94.85	69.51	36.39	4.47	32.06	10.58	28.24	5.69	20.23	6.93
Isoamyl alcohol	262585.2	34552.25	253579.05	9414.40	236328.56	14543.81	267963.29	5736.69	216584.40	4092.48
1-Pentanol	54.65	4.48	71.71	11.03	88.71	61.35	53.29	3.45	66.24	3.06
Phenylethyl alcohol	20052.01	7467.71	10577.29	616.61	9170.53	1363.71	12250.09	1111.84	8764.16	131.76
Methionol	305.51	6.80	219.23	2.31	158.11	92.34	284.78	15.70	95.01	51.88
C_6 alcohols										
1-Hexanol	883.34	45.95	1143.46	135.42	816.29	28.26	667.78	86.53	1552.55	132.83
trans-3-Hexen-1-ol	7.47	1.30	8.54	0.43	6.40	0.44	5.02	0.34	11.61	1.42
cis-3-Hexen-1-ol	262.00	28.94	458.76	76.39	240.45	9.19	207.10	35.18	312.45	6.06
cis-2-Hexen-1-ol	12.07	5.47	3.69	0.47	3.90	0.29	2.52	0.26	5.90	0.95
Acetate esters										
Isoamyl acetate	470.01	69.82	633.15	80.80	720.67	72.57	558.78	21.30	626.29	23.18
2-Phenethyl acetate	33.39	2.93	31.24	4.87	44.51	2.34	41.32	1.81	37.06	1.40
n-Hexyl acetate	2.41	0.35	5.32	0.91	5.26	0.42	3.73	0.45	7.89	1.13
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	8.80	0.11	5.41	0.10	11.74	0.12	8.77	0.15	8.69	0.13
Ethyl 3-methylbutanoate	9.50	0.21	4.95	0.05	11.81	0.06	8.26	0.27	9.05	0.14
Ethyl fatty acids esters										
Ethyl lactate	341.64	97.64	683.75	36.29	972.84	86.46	341.74	5.87	803.78	3.67
Ethyl butanoate	162.14	3.82	181.29	2.63	170.12	2.94	155.67	3.76	172.25	1.63
Ethyl 3-hydroxybutanoate	258.95	36.84	309.81	36.21	345.18	11.84	235.56	27.25	326.60	23.46
Ethyl hexanoate	503.74	44.75	571.24	19.39	535.30	16.29	467.12	17.64	533.09	33.90
Ethyl octanoate	257.28	21.60	310.07	9.63	311.01	12.70	290.71	11.65	278.54	20.74
Ethyl decanoate	46.60	1.61	53.21	6.57	58.31	5.85	58.34	2.06	57.37	4.62
Ethyl cinnamate	1.47	0.39	3.38	0.77	1.71	0.10	1.03	0.16	2.50	0.17
Fatty acids										
3-Methylbutanoic acid	446.42	12.64	344.02	30.26	327.07	24.40	421.37	17.00	251.91	27.27
Hexanoic acid	2025.55	22.60	2923.94	118.56	2358.62	31.67	1971.99	158.95	2407.68	118.34
Octanoic acid	4538.79	119.99	5019.93	18.32	4861.23	18.83	4567.46	130.07	4706.86	165.58
Terpenoids										
cis-Linaloloxide	0.38	0.37	0.00	0.00	1.17	2.03	0.00	0.00	0.00	0.00

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
trans-Linaloloxide	0.91	0.13	1.25	0.07	1.10	0.10	0.53	0.14	1.52	0.55
Linalool	4.38	0.55	26.94	4.43	22.61	3.81	11.18	1.15	32.47	1.39
Terpinen-4-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
α-Terpineol	1.30	0.24	11.27	2.31	12.67	0.74	2.90	0.48	14.03	2.28
β-Citronellol	14.76	1.59	11.71	0.02	10.01	1.13	11.42	1.49	7.99	0.48
Geraniol	8.57	0.40	6.78	1.16	6.03	1.31	8.13	1.16	6.92	0.49
α-Phellandrene	0.13	0.02	1.08	0.24	1.09	0.12	0.30	0.03	1.67	0.32
α-Terpinen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.06
Limonene	0.26	0.01	2.96	0.46	2.72	0.40	0.88	0.14	3.84	0.96
1,8-Cineol	0.01	0.00	0.03	0.00	0.03	0.01	0.02	0.00	0.06	0.04
p-Cymene	0.07	0.01	0.56	0.14	0.53	0.08	0.20	0.02	0.71	0.27
Terpinolene	0.14	0.01	1.93	0.35	1.60	0.06	0.47	0.04	3.11	0.21
Nerol	0.37	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p-Cymenene	0.25	0.01	2.29	0.48	2.15	0.22	0.79	0.13	2.55	0.51
Norisoprenoids										
β-Damascenone	2.08	0.45	3.71	0.39	4.59	0.54	1.57	0.17	5.70	0.56
3-Hydroxy-βa-damascone	0.11	0.01	0.13	0.01	0.08	0.01	0.09	0.01	0.10	0.01
Vitispirane	1.66	0.92	1.63	0.77	0.84	0.57	1.50	0.08	3.75	0.59
TPB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
TDN	0.16	0.07	0.21	0.08	0.15	0.06	0.23	0.02	0.49	0.10
Benzenoids and others										
Furfural	0.00	0.00	0.00	0.00	0.49	0.42	0.00	0.00	0.00	0.00
Benzaldehyde	6.30	1.86	1.48	0.20	7.02	1.39	3.44	0.29	2.82	0.23
Benzyl Alcohol	126.11	8.11	97.45	4.59	83.54	3.23	146.08	8.57	84.62	7.39
Vanillin	4.96	0.88	4.51	0.52	2.76	0.40	3.71	0.10	3.88	1.05
Methyl-vanillate	2.91	2.59	7.52	0.07	9.09	0.64	7.04	0.48	14.33	0.64
Ethyl-vanillate	144.81	12.57	128.58	10.47	126.47	7.89	144.64	13.53	151.63	2.74
Methyl-salycilate	0.17	0.04	0.40	0.03	0.56	0.20	1.71	0.30	0.65	0.04
2-6-Dimethoxyphenol	5.83	5.05	10.38	0.48	8.34	0.88	8.57	0.30	9.67	2.92
Eugenol	3.15	0.22	5.44	0.36	3.45	0.17	5.03	0.06	4.52	0.18
γ-Nonalactone	13.13	1.77	10.80	0.38	13.54	0.35	10.88	0.92	21.95	1.67

Appendix 1.3.1.11. Concentration (μg/L) and standard deviation (± μg/L) of volatile compounds of 2017 Corvinone wines

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	57.40	8.74	91.23	5.98	93.67	5.78	133.09	6.89	90.52	3.50
Isoamyl alcohol	275966.64	4821.40	251937.23	12611.56	309961.34	884.37	302675.55	5164.05	347173.47	10508.20
1-Pentanol	61.85	3.17	95.98	8.57	74.57	2.84	97.96	1.90	86.04	3.03
Phenylethyl alcohol	20706.43	2345.27	14104.41	86.75	20043.65	648.84	13332.66	9435.52	21054.63	624.64
Methionol	280.74	32.49	237.10	61.91	400.87	27.59	357.89	12.78	404.95	6.86
C_6 alcohols										
1-Hexanol	2169.60	0.69	2102.76	81.88	1580.97	18.76	1843.82	91.43	2263.93	76.44
trans-3-Hexen-1-ol	19.13	0.65	20.73	0.14	16.12	0.88	16.69	0.68	23.63	2.23
cis-3-Hexen-1-ol	95.06	1.59	57.71	3.98	54.83	0.08	63.37	8.98	61.22	0.18
cis-2-Hexen-1-ol	4.63	0.84	4.13	0.49	2.74	0.15	3.30	0.20	4.76	0.67
Acetate esters										
Isoamyl acetate	283.97	10.49	356.08	13.72	296.31	14.12	847.50	73.39	363.06	2.29
2-Phenethyl acetate	34.22	0.55	26.96	0.10	28.21	0.85	33.78	2.65	38.44	1.09
n-Hexyl acetate	4.67	0.31	6.09	0.08	3.89	0.54	7.91	0.65	9.51	0.31
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	11.24	0.17	5.96	0.17	8.12	0.05	5.85	0.80	7.61	0.18
Ethyl 3-methylbutanoate	9.90	1.04	5.92	0.88	8.31	0.50	6.53	0.37	7.05	0.99
Ethyl fatty acids esters										
Ethyl lactate	1192.01	113.79	1222.57	9.98	1810.08	69.41	977.64	139.18	1623.79	37.23
Ethyl butanoate	96.99	3.57	100.26	0.22	118.00	3.80	208.63	7.55	112.40	1.57
Ethyl 3-hydroxybutanoate	163.28	5.80	184.44	11.59	227.16	4.33	232.73	8.48	220.67	9.64
Ethyl hexanoate	250.42	15.49	210.82	7.03	304.60	7.78	475.00	16.68	329.62	5.29
Ethyl octanoate	125.31	10.95	116.08	9.82	175.96	13.12	286.41	15.33	161.49	2.90
Ethyl decanoate	21.43	1.83	23.34	2.52	30.96	1.60	50.89	6.24	26.64	1.53
Ethyl cinnamate	0.22	0.01	0.15	0.03	0.31	0.07	0.12	0.02	0.07	0.01
Fatty acids										
3-Methylbutanoic acid	418.57	61.56	335.75	2.29	415.54	10.16	408.59	40.18	351.89	8.55
Hexanoic acid	1999.07	97.89	1819.19	29.28	2342.02	83.25	3577.59	121.51	2159.51	31.21
Octanoic acid	1520.37	66.47	1480.89	41.29	2154.85	103.73	2882.80	143.94	2012.03	30.02
Terpenoids										
cis-Linaloloxide	0.87	0.07	0.42	0.04	0.58	0.16	0.68	0.18	0.71	0.18
trans-Linaloloxide	0.88	0.17	0.64	0.17	0.61	0.24	0.64	0.28	0.52	0.04

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Linalool	19.44	0.04	6.35	0.04	11.38	0.63	8.32	0.52	19.23	0.61
Terpinen-4-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
α-Terpineol	5.79	0.26	2.63	0.02	3.86	0.28	2.22	0.21	7.26	0.67
β-Citronellol	6.82	0.70	6.48	0.51	5.52	0.45	9.90	0.82	6.82	0.14
Geraniol	4.61	0.06	3.64	0.29	5.94	0.48	6.82	1.16	5.43	0.08
α-Phellandrene	0.21	0.01	0.22	0.01	0.29	0.01	0.48	0.07	0.23	0.04
α-Terpinen	0.02	0.00	0.03	0.00	0.06	0.00	0.05	0.01	0.05	0.00
1,4-Cineol	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Limonene	0.14	0.00	0.13	0.00	0.14	0.01	0.24	0.01	0.20	0.01
1,8-Cineol	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
p-Cymene	0.10	0.01	0.11	0.01	0.14	0.03	0.12	0.01	0.12	0.00
Terpinolene	0.07	0.00	0.09	0.01	0.12	0.02	0.24	0.04	0.16	0.01
Nerol	1.06	0.06	1.10	0.11	1.89	0.22	0.29	0.22	0.53	0.69
p-Cymenene	0.06	0.00	0.09	0.00	0.12	0.01	0.17	0.02	2.16	0.16
Norisoprenoids										
β-Damascenone	4.35	0.18	10.66	0.02	10.87	0.20	7.27	0.21	8.63	0.09
3-Hydroxy-βa-damascone	0.08	0.01	0.09	0.01	0.10	0.02	0.07	0.01	0.09	0.01
Vitispirane	11.34	0.26	15.11	1.16	19.33	0.49	13.19	1.59	21.97	1.27
TPB	0.05	0.00	0.10	0.01	0.11	0.01	0.13	0.11	0.10	0.01
TDN	4.76	0.16	8.25	0.83	12.33	0.40	5.62	1.28	11.32	0.04
Benzenoids and others										
Furfural	2.56	0.09	2.81	0.41	3.32	0.01	3.62	0.21	3.09	0.16
Benzaldehyde	15.08	0.04	15.02	0.12	14.82	0.04	14.68	0.14	15.11	0.15
Benzyl Alcohol	14.99	4.85	4.06	4.06	10.75	2.58	6.96	0.70	10.78	1.42
Vanillin	7.77	0.91	6.98	1.08	7.49	0.39	8.48	2.88	6.07	0.16
Methyl-vanillate	10.53	0.14	7.64	0.19	9.79	0.08	9.33	0.12	16.18	0.66
Ethyl-vanillate	50.50	0.33	76.40	0.56	69.57	1.72	79.26	3.24	76.01	7.29
Methyl-salycilate	<LOQ		<LOQ		<LOQ		<LOQ		<LOQ	
2-6-Dimethoxyphenol	4.99	0.03	5.50	0.31	5.31	0.10	5.13	0.78	5.10	0.01
Eugenol	0.51	0.04	0.80	0.08	0.83	0.07	0.89	0.07	0.94	0.20
γ-Nonalactone	19.39	1.10	19.02	0.34	18.37	0.89	12.60	0.41	18.34	0.55

Appendix 1.3.1.12. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2018 Corvinone wines										
	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	125.78	9.67	169.71	12.42	165.79	22.97	146.99	18.43	141.59	1.28
Isoamyl alcohol	243821.28	14006.35	223209.90	12650.18	201768.17	8349.16	258276.80	5000.60	226655.28	726.05
1-Pentanol	66.67	0.25	86.77	0.42	102.42	1.46	53.43	0.64	88.76	1.53
Phenylethyl alcohol	17904.74	944.12	18515.59	1654.69	14537.03	849.96	20527.65	366.71	17333.09	629.84
Methionol	392.13	71.63	484.09	45.51	367.90	15.65	741.26	71.73	343.16	15.56
C_6 alcohols										
1-Hexanol	1729.16	37.65	1335.59	58.98	2116.14	42.78	969.57	15.58	1750.26	102.08
trans-3-Hexen-1-ol	14.90	0.85	16.95	0.43	28.06	0.77	8.75	0.18	25.14	1.53
cis-3-Hexen-1-ol	89.69	2.60	48.54	2.81	37.74	3.26	35.47	0.65	40.55	0.65
cis-2-Hexen-1-ol	12.10	0.29	13.71	0.62	12.68	0.25	13.43	0.23	13.48	0.51
Acetate esters										
Isoamyl acetate	817.38	65.70	832.61	77.49	891.52	4.90	1321.54	52.77	526.79	30.12
2-Phenethyl acetate	29.42	1.46	32.30	1.67	27.48	2.08	71.17	5.60	24.48	0.73
n-Hexyl acetate	7.19	0.32	6.91	0.20	10.01	0.54	8.78	0.13	5.13	0.04
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	4.98	0.07	4.30	0.04	3.84	0.23	4.25	0.25	3.68	0.03
Ethyl 3-methylbutanoate	4.86	0.05	3.50	0.14	3.23	0.15	3.53	0.03	3.58	0.29
Fatty acids ethyl esters										
Ethyl lactate	605.17	53.70	753.81	12.54	618.38	56.30	559.77	14.86	641.35	11.17
Ethyl butanoate	159.31	5.24	123.70	5.04	159.83	14.56	110.82	3.31	110.40	2.36
Ethyl 3-hydroxybutanoate	306.60	56.71	198.05	6.14	232.30	33.32	217.34	8.66	207.24	4.72
Ethyl hexanoate	429.15	45.07	303.40	4.59	404.09	27.83	282.13	11.01	302.97	10.45
Ethyl octanoate	205.79	35.78	159.90	7.06	197.37	8.10	145.95	19.92	136.25	16.08
Ethyl decanoate	25.29	5.07	23.79	1.26	25.72	2.37	30.59	9.25	18.08	2.08
Ethyl cinnamate	0.38	0.05	0.33	0.24	0.07	0.05	0.06	0.07	0.16	0.07
Fatty acids										
3-Methylbutanoic acid	470.98	11.22	381.90	11.80	353.43	6.98	529.67	28.73	345.70	18.18
Hexanoic acid	2629.42	156.30	2314.79	29.26	3223.66	407.87	1891.64	39.36	2302.20	58.00
Octanoic acid	4761.97	153.45	4506.91	35.74	5155.71	343.60	4294.45	74.78	4142.90	150.94
Terpenoids										
cis-Linaloloxide	0.67	0.51	0.58	0.75	0.26	0.20	0.20	0.06	0.65	0.76
trans-Linaloloxide	0.15	0.18	0.04	0.01	0.29	0.44	0.12	0.14	0.05	0.02

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Linalool	4.30	0.24	5.68	0.16	5.08	0.13	5.90	0.36	10.39	0.67
Terpinen-4-ol	0	0	0	0	0	0	0	0	0	0
α-Terpineol	1.35	0.17	1.34	0.04	0.65	0.02	1.31	0.08	3.43	0.17
β-Citronellol	10.28	0.06	12.37	1.43	9.78	0.73	12.71	0.25	11.06	0.02
Geraniol	5.73	0.30	2.66	0.13	2.79	0.18	2.77	0.11	1.18	0.09
α-Phellandrene	1.06	0.07	0.56	0.09	0.49	0.08	0.58	0.04	0.45	0.06
α-Terpinen	0.04	0.01	0.03	0.00	0.02	0.00	0.02	0.01	0.11	0.02
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Limonene	0.22	0.01	0.12	0.01	0.11	0.01	0.28	0.02	0.36	0.06
1,8-Cineol	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
p-Cymene	0.15	0.01	0.10	0.02	0.10	0.02	0.10	0.01	0.14	0.03
Terpinolene	0.23	0.02	0.12	0.00	0.10	0.01	0.18	0.07	0.53	0.08
Nerol	1.13	0.14	0.62	0.11	0.72	0.07	0.32	0.05	0.01	0.00
p-Cymenene	0.15	0.05	0.13	0.01	0.14	0.02	0.17	0.02	0.18	0.12
Norisoprenoids										
β-Damascenone	3.14	0.05	3.04	0.02	2.32	0.10	1.57	0.06	2.48	0.05
3-Hydroxy-βa-damascone	0.08	0.01	0.09	0.01	0.06	0.02	0.05	0.00	0.10	0.01
Vitispirane	0.54	0.02	0.62	0.02	0.61	0.04	4.82	0.62	17.94	2.06
TPB	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.08	0.03
TDN	0.10	0.01	0.09	0.01	0.09	0.01	0.52	0.16	5.24	0.96
Benzenoids and others										
Furfural	1.54	0.09	0.98	0.39	1.38	0.04	1.14	0.06	1.12	0.08
Benzaldehyde	14.81	0.45	15.30	0.93	14.76	0.20	14.37	0.15	14.50	0.04
Benzyl Alcohol	24.49	0.83	16.72	0.19	10.54	0.61	9.26	0.17	8.81	0.48
Vanillin	5.80	0.09	4.99	0.31	4.85	0.25	3.95	0.22	5.89	0.33
Methyl-vanillate	18.90	0.85	9.10	0.52	10.98	0.40	11.23	0.19	16.53	0.43
Ethyl-vanillate	140.36	3.42	121.72	2.69	130.69	7.51	127.22	2.50	175.29	2.83
Methyl-salycilate	0.41	0.04	0.56	0.07	0.33	0.04	0.34	0.01	0.69	0.23
2-6-Dimethoxyphenol	11.73	1.65	8.89	0.09	8.60	0.23	7.30	0.33	10.05	0.19
Eugenol	0.89	0.04	1.01	0.15	1.02	0.02	0.48	0.09	0.70	0.02
γ-Nonalactone	12.74	0.53	11.64	0.75	13.47	1.10	11.60	1.01	13.29	0.68

Appendix 1.3.1.13. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2019 Corvinone wines										
	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	60.33	40.03	61.06	60.48	72.39	54.09	52.47	27.25	31.51	5.60
Isoamyl alcohol	237074.69	26964.91	271235.23	13602.57	217956.19	12141.35	280859.11	4409.90	224967.94	10859.47
1-Pentanol	55.07	3.40	86.73	6.90	81.70	12.78	94.01	50.58	92.92	3.24
Phenylethyl alcohol	11443.12	406.39	11141.40	599.16	12925.41	2155.45	15338.38	0.00	9864.84	764.35
Methionol	111.34	26.00	161.66	10.06	188.50	122.85	242.93	0.32	64.17	32.50
C6 alcohols										
1-Hexanol	709.37	127.31	2059.77	61.97	1128.42	92.78	1330.13	50.70	2320.19	159.59
trans-3-Hexen-1-ol	9.39	1.82	27.94	0.87	16.88	0.43	17.99	0.82	46.82	0.51
cis-3-Hexen-1-ol	19.44	1.25	64.95	6.45	25.01	0.60	42.51	0.00	46.04	0.77
cis-2-Hexen-1-ol	3.34	0.31	10.57	0.80	5.66	0.54	6.78	0.97	18.30	1.50
Acetate esters										
Isoamyl acetate	489.85	49.43	567.90	7.09	589.40	81.12	803.94	5.91	732.06	33.66
2-Phenethyl acetate	43.43	3.18	35.26	0.53	30.71	0.82	60.19	13.37	39.41	0.75
n-Hexyl acetate	3.14	0.56	10.02	0.47	5.26	0.24	12.06	1.94	16.51	1.68
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	8.10	0.10	5.11	0.11	5.99	0.07	5.01	0.10	5.67	0.14
Ethyl 3-methylbutanoate	7.47	0.16	4.74	0.13	5.73	0.07	5.01	0.13	5.28	0.21
Fatty acids ethyl esters										
Ethyl lactate	424.26	104.69	505.93	59.04	494.58	59.23	395.5	80.68	701.11	6.62
Ethyl butanoate	128.63	4.50	155.63	0.88	109.95	81.50	170.91	3.00	160.04	2.48
Ethyl 3-hydroxybutanoate	247.64	36.84	289.68	22.86	318.82	20.03	320.97	0.01	344.83	14.10
Ethyl hexanoate	395.06	46.88	487.69	7.53	473.36	21.20	536.66	12.27	503.80	9.11
Ethyl octanoate	227.13	22.61	256.32	11.45	286.40	14.84	298.76	0.26	259.06	11.07
Ethyl decanoate	48.05	7.32	50.50	3.76	56.75	4.87	58.57	0.27	49.77	2.69
Ethyl cinnamate	2.14	0.64	2.08	0.20	1.17	0.16	0.79	0.00	1.52	0.03
Fatty acids										
3-Methylbutanoic acid	343.88	45.18	420.99	20.21	333.23	9.51	428.62	0.39	246.94	15.88
Hexanoic acid	1616.28	209.98	2453.85	85.18	2455.20	116.86	2347.21	0.20	2456.11	57.38
Octanoic acid	3997.85	341.61	4636.46	42.39	5063.08	146.82	5182.70	0.06	4594.77	85.81
Terpenoids										
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.15	0.26	0.07	7.94	0.00	0.00
trans-Linaloloxide	0.81	0.01	0.63	0.03	0.81	0.27	0.01	0.27	0.65	0.07
Linalool	10.48	1.90	7.80	0.62	7.77	1.38	10.40	0.95	15.10	1.62
Terpinen-4-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
α-Terpineol	3.25	0.65	2.47	0.41	1.98	0.36	3.90	0.40	6.22	0.34
β-Citronellol	5.23	0.29	8.97	1.72	8.42	0.32	9.29	0.53	8.85	1.65
Geraniol	5.03	0.58	4.00	0.66	4.77	1.15	5.74	0.00	3.35	0.30
α-Phellandrene	0.33	0.05	0.13	0.02	0.17	0.03	0.25	0.02	0.41	0.03
α-Terpinen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limonene	0.93	0.17	0.58	0.06	0.49	0.04	0.82	0.08	1.25	0.19
1,8-Cineol	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00
p-Cymene	0.19	0.02	0.12	0.02	0.11	0.02	0.15	0.02	0.25	0.01
Terpinolene	0.53	0.08	0.31	0.04	0.25	0.05	0.47	0.01	0.95	0.13
Nerol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48	0.00	0.00
p-Cymenene	0.66	0.10	0.54	0.08	0.56	0.04	0.64	0.05	1.08	0.15
Norisoprenoids										
β-Damascenone	1.39	0.33	2.91	0.24	5.21	0.21	5.86	0.15	4.41	0.88
3-Hydroxy-βa-damascone	0.08	0.02	0.08	0.02	0.15	0.04	0.08	46.80	0.08	0.01
Vitispirane	1.66	0.92	2.06	0.30	1.12	0.64	1.50	0.08	3.75	0.59
TPB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
TDN	0.16	0.07	0.21	0.08	0.15	0.06	0.23	0.02	0.49	0.10
Benzenoids and others										
Furfural	0.00	0.00	0.00	0.00	0.15	0.27	0.15	0.12	0.00	0.00
Benzaldehyde	1.48	0.19	1.49	0.17	4.12	0.74	2.30	23.62	2.42	0.09
Benzyl Alcohol	19.30	3.70	15.18	2.28	22.39	3.33	17.19	132.29	28.23	3.77
Vanillin	3.34	0.02	4.19	0.41	5.53	0.58	2.36	0.69	4.45	0.31
Methyl-vanillate	16.56	2.06	17.72	1.21	17.97	1.07	11.59	4.86	22.92	0.37
Ethyl-vanillate	144.92	14.21	195.62	8.30	219.04	1.50	128.91	1.00	160.14	5.38
Methyl-salycilate	0.46	0.04	0.40	0.01	0.98	0.15	0.86	0.00	0.54	0.07
2-6-Dimethoxyphenol	11.88	1.58	13.85	0.82	10.27	1.67	8.97	0.32	7.78	0.19
Eugenol	0.63	0.03	0.77	0.01	1.62	0.07	0.69	1.13	0.73	0.06
γ-Nonalactone	11.84	0.48	13.22	0.36	16.52	1.29	11.98	2.38	20.29	1.26

Appendix 1.3.1.14. Significant different compounds in Corvina fresh wines according to Kruskal Wallis (α=0.05) multiple pairwise comparisons Steel-Dwass-Critchlow-Fligner

	Vineyard 1	Vineyard 2	Vineyard 3	Vineyard 4	Vineyard 5	Pr > F
Linalool	a	b	ab	ab	c	<0.0001
β-Citronellol	d	bc	ab	c	a	<0.0001
TDN	a	bc	bc	ab	c	<0.0001
Ethyl-3-methylbutanoate	c	a	d	b	bc	<0.0001
Ethyl lactate	a	b	b	a	b	<0.0001
1,8-Cineol	ab	b	b	a	c	<0.0001
Ethyl-2-methylbutanoate	b	a	c	b	b	<0.0001
Vitispirane	a	a	a	a	b	<0.0001
2-Phenethyl acetate	ab	a	c	c	bc	<0.0001
α-Terpineol	a	cd	bc	ab	d	<0.0001
trans-3-Hexen-1-ol	ab	b	b	a	b	<0.0001
Methyl-vanillate	a	a	a	a	b	<0.0001
3-Methylbutanoic acid	b	a	b	b	a	<0.0001
TPB	b	b	b	b	a	0.000
1-Pentanol	a	b	ab	a	ab	0.000
1-Hexanol	ab	b	b	a	b	0.000
cis-Linaloloxide	ab	b	b	a	b	0.000
Methionol	a	a	a	b	a	0.000
Methyl-salycilate	a	a	a	b	a	0.000
Benzyl alcohol	c	ab	a	bc	a	0.000
1,4-Cineol	a	a	a	a	b	0.000
Geraniol	b	a	a	a	a	0.000
p-Cymene	a	ab	ab	ab	b	0.000
n-Hexyl acetate	a	ab	b	ab	b	0.001
Eugenol	a	b	ab	a	a	0.001
γ-Nonalactone	ab	ab	ab	a	b	0.001
Isoamyl acetate	a	ab	b	b	b	0.001
Vanillin	b	a	a	a	a	0.001
cis-3-Hexen-1-ol	ab	b	ab	a	ab	0.002
Limonene	a	b	b	b	b	0.002
3-Hydroxy-β-damascone	ab	ab	ab	b	a	0.002
Terpinolene	b	a	a	a	a	0.002
Phenylethyl alcohol	b	a	ab	b	ab	0.003
p-Cymene	b	ab	ab	ab	a	0.003
Ethyl cinnamate	a	a	a	a	a	0.006
Ethyl 3-hydroxybutanoate	ab	b	b	a	ab	0.015
β-damascenone	ab	b	ab	a	b	0.017
α-Phellandrene	a	b	b	ab	ab	0.022
Furfural	ab	ab	b	ab	a	0.034
Isoamyl alcohol	ab	a	ab	b	ab	0.050

Appendix 1.3.1.15. Significant different compounds in Corvinone fresh wines according to Kruskal Wallis (α=0.05) multiple pairwise comparisons Steel-Dwass-Critchlow-Fligner

	Vineyard 1	Vineyard 2	Vineyard 3	Vineyard 4	Vineyard 5	Pr > F
Linalool	a	a	a	a	b	<0.0001
Limonene	b	ab	a	c	c	<0.0001
Terpinolene	ab	a	ab	bc	c	<0.0001
α-Terpineol	b	ab	a	ab	c	<0.0001
Methyl-vanillate	bc	a	ab	a	c	<0.0001
trans-3-Hexen-1-ol	ab	b	b	a	c	<0.0001
2-Phenethyl acetate	a	a	a	b	a	<0.0001
cis-2-Hexen-1-ol	a	bc	a	ab	c	0.000
Isoamyl acetate	a	a	a	b	a	0.000
γ-Nonalactone	abc	ab	bc	a	c	0.000
β-Citronellol	a	bc	ab	c	abc	0.000
Ethyl 3-methylbutanoate	b	a	a	a	a	0.000
3-Methylbutanoic acid	bc	abc	ab	c	a	0.000
Ethyl decanoate	a	a	ab	b	a	0.000
Ethyl-2-methylbutanoate	b	a	a	a	a	0.000
Ethyl lactate	ab	bc	bc	a	c	0.001
Nerol	b	b	b	a	ab	0.001
Vitispirane	a	a	a	a	b	0.002
Geraniol	b	a	ab	b	a	0.002
TDN	a	a	a	a	b	0.002
Ethyl cinnamate	a	a	a	a	a	0.003
Octanoic acid	a	abc	c	bc	ab	0.003
TPB	a	a	a	a	b	0.005
p-Cymene	ab	a	a	a	b	0.005
α-Phellandrene	b	a	a	ab	ab	0.007
1,8-Cineol	ab	ab	a	ab	b	0.007
1-Pentanol	a	b	b	ab	b	0.009
Eugenol	a	ab	b	a	ab	0.010
Methionol	a	a	ab	b	a	0.010
α-Terpinen	a	a	ab	ab	b	0.012
Isoamyl alcohol	ab	ab	a	b	ab	0.013
1-Hexanol	ab	ab	ab	a	b	0.014
1-Butanol	a	a	a	a	a	0.021
Ethyl octanoate	a	a	a	a	a	0.022
1,4-Cineol	a	a	a	a	a	0.031
2-6-Dimethoxy-phenol	a	a	a	a	a	0.036
cis-3-Hexen-1-ol	b	ab	a	ab	ab	0.044
n-Hexyl acetate	a	ab	ab	b	ab	0.044
Benzyl Alcohol	b	a	ab	a	ab	0.047
β-damascenone	a	a	a	a	a	0.050

Appendix 1.3.2.1. Main enological parameters of withered grapes at crush

	PAN (mg/L)		Ammonia (mg/L)		YAN (mg/L)		Glucose + fructose (g/ L)		pH	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Corvina 2017										
Vineyard 1	53.0 lm	2.8	21.0 m	1.4	70.3 op	4.0	345.8 a	6.7	2.91 m	0.01
Vineyard 2	156.5 a	0.7	107.5 ab	6.4	244.9 a	4.5	279.3 d	6.0	3.21 a	0.01
Vineyard 3	93.5 efg	3.5	86.5 cdf	2.1	164.6 cde	5.3	319.0 b	14.8	3.01 efgh	0.01
Vineyard 4	63.0 jkl	2.0	27.3 lm	5.1	85.5 mno	6.2	324.0 ab	3.8	2.99 fghi	0.01
Vineyard 5	131.0b	3.5	84.7 def	3.1	200.6 b	1.4	278.0 de	9.3	2.97 hijk	0.02
Corvina 2018										
Vineyard 1	64.7 hijk	2.6	25.2m	1.2	82.6 mno	1.7	255.6 efghi	19.1	3.01 efg	0.01
Vineyard 2	107.8 cd	7.5	83.8 cdf a	13.9	178.8 cd	18.6	253.3fghi	7.0	3.06 cd	0.03
Vineyard 3	160.3 a	3.5	108.3 ab	1.0	249.4 a	3.9	272.3 defg	10.8	3.00 efgh	0.02
Vineyard 4	70.7 hijk	5.7	35.7 jklm	3.0	100.0 klmn	8.1	305.3 b	2.8	3.21 a	0.02
Vineyard 5	114.7 bcd	5.0	94.7 bcd	8.6	192.5 b	12.1	262.4 defg	1.5	3.02 def	0.02
Corvina 2019										
Vineyard 1	76.1 dghij	3.5	20.9 m	3.1	88 mno	6.0	319.3 b	5.2	3.04 de	0.01
Vineyard 2	121.1 bc	4.0	85.7 def	1.0	191.6 b	4.4	303.0 bc	7.8	2.82 n	0.01
Vineyard 3	68.1 ijkl	14.3	84.2 def	13.3	137.3 fgh	25.2	318.0 b	3.3	2.73 o	0.01
Vineyard 4	44.5 m	1.2	33.4 klm	1.5	71.9 op	2.3	324.3 ab	2.3	3.06 cd	0.01
Vineyard 5	114.7 bcd	3.5	101.1 bc	4.7	197.9 b	4.9	314.3 b	0.9	2.91 m	0.02
Corvinone 2017										
Vineyard 1	40.0 m	3.5	23.3 m	4.7	59.2 p	4.9	260.0 defgh	0.9	2.96 ijkl	0.02
Vineyard 2	82.0 fghi	3.6	68.0 gh	1.5	137.9 fgh	4.8	261.3 defg	8.7	3.09 bc	0.01
Vineyard 3	70.3 hijk	1.7	43.0 jk	0.6	105.7 jklm	1.3	261.5 defg	7.0	3.05 cd	0.01
Vineyard 4	54.3 klm	5.0	30.0 klm	1.5	79.0 nop	4.4	306.5 b	4.2	3.12 b	0.01
Vineyard 5	81.7 fghi	5.3	71.7fgh	6.1	140.6 efg	6.3	273.7 def	1.9	3.12 b	0.02
Corvinone 2018										
Vineyard 1	94.0 efg	7.9	59.3 hi	1.8	142.8 efg	9.3	238.7 hi	4.7	3.01 efg	0.02
Vineyard 2	113.0 cd	1.7	87.3 cde	8.5	184.8 bcd	5.3	233.4 i	7.0	3.09 bc	0.01
Vineyard 3	153.3 a	2.7	94.7 bcd	4.4	231.2 a	5.8	280.8 cd	3.0	3.12 b	0.01
Vineyard 4	90.0 efg	0.8	49.0 ij	1.1	130.3ghij	1.6	274.6 def	2.1	3.17 a	0.02
Vineyard 5	95.7 ef	6.5	80.0 fgh	2.1	161.5 def	8.0	250.0 ghi	0.6	2.94 klm	0.02
Corvinone 2019										
Vineyard 1	82.7 fghi	4.0	38.2 jkl	1.7	114.1 hijkl	4.2	325.3 ab	1.5	2.76 o	0.02
Vineyard 2	44.7 m	1.8	58.2 hi	3.4	92.6 lmno	1.1	255.7 efghi	4.2	2.83 n	0.02
Vineyard 3	77.4 ghij	0.7	61.5 hi	2.3	128.0 ghij	1.8	260.7 defgh	4.7	2.95 jklm	0.00
Vineyard 4	43.3 m	2.2	31.5 klm	3.1	69.2 op	1.6	275.7 def	4.2	2.92 lm	0.02
Vineyard 5	98.4 def	11.8	107.7 ab	1.9	187.0 bc	13.3	310.0b	3.6	2.98 ghij	0.01

Values in the same column with different letters indicate statistically significant differences (α=< 0.05) according to ANOVA.

Appendix 1.3.2.2. Enological parameters of withered grapes musts at the end of alcoholic fermentation.

		Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
		mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Corvina 2017	Total acidity (g/L)	6.8	0.1	7.6	0.1	7.7	0.1	6.6	0.1	8.3	0.1
	pH	3.20	0.01	3.28	0.01	3.28	0.01	3.19	0.01	3.16	0.01
	Acetic acid (g/L)	0.64	0.01	0.17	0.03	0.29	0.04	0.33	0.04	0.19	0.04
	Ethanol (% v/v)	19.1	0.3	15.5	0.2	17.9	0.5	18.2	0.2	15.7	0.5
Corvina 2018	Total acidity (g/L)	6.5	0.1	7.8	0.2	7.7	0.1	6.7	0.1	10.1	0.3
	pH	3.45	0.01	2.88	0.03	2.92	0.03	3.52	0.01	2.58	0.04
	Acetic acid (g/L)	0.11	0.03	0.21	0.02	0.22	0.01	0.56	0.03	0.32	0.02
	Ethanol (% v/v)	14.4	0.4	14.4	0.4	15.4	0.5	17.4	0.3	14.7	0.1
Corvina 2019	Total acidity (g/L)	5.6	0.1	6.3	0.1	6.9	0.1	5.7	0.2	6.6	0.1
	pH	3.56	0.03	2.90	0.01	2.70	0.04	2.91	0.01	2.99	0.01
	Acetic acid (g/L)	0.86	0.04	0.45	0.10	0.87	0.04	1.00	0.02	1.00	0.01
	Ethanol (% v/v)	18.0	0.1	17.3	0.4	17.9	0.5	18.2	0.4	17.6	0.2
Corvinone 2017	Total acidity (g/L)	7.6	0.1	7.3	0.1	6.8	0.1	7.0	0.1	8.3	0.1
	pH	3.18	0.01	3.20	0.01	3.20	0.02	3.18	0.01	3.16	0.01
	Acetic acid (g/L)	0.17	0.03	0.17	0.03	0.16	0.03	0.38	0.05	0.16	0.03
	Ethanol (% v/v)	14.7	1.3	14.8	0.2	14.7	0.8	17.1	0.1	15.7	0.2
Corvinone 2018	Total acidity (g/L)	7.6	0.1	7.9	0.1	7.2	0.1	7.3	0.2	9.0	0.1
	pH	3.23	0.01	2.93	0.01	3.28	0.01	3.38	0.03	2.81	0.03
	Acetic acid (g/L)	0.15	0.02	0.17	0.06	0.20	0.02	0.15	0.03	0.19	0.05
	Ethanol (% v/v)	13.4	0.4	13.1	0.5	15.9	0.3	15.5	0.2	14.0	0.5
Corvinone 2019	Total acidity (g/L)	6.7	0.2	6.4	0.1	6.2	0.1	5.3	0.3	6.4	0.1
	pH	3.49	0.01	2.96	0.03	3.08	0.01	3.24	0.03	2.96	0.01
	Acetic acid (g/L)	0.99	0.02	0.25	0.01	0.28	0.04	0.40	0.03	0.79	0.02
	Ethanol (% v/v)	18.4	0.2	14.6	0.4	14.7	0.4	15.5	0.1	17.6	0.4

Appendix 1.3.2.3. Two-way ANOVA (α=0.05) of volatile compounds of withered grapes wines according to different vineyards and vintages.

	Corvina						**Corvinone**					
	Vineyard		Vintage		*Vineyard*Vintage*		*Vineyard*		*Vintage*		*Vineyard*Vintage*	
	Pr > F	*Significant*	*Pr > F*	*Significant*	*Pr > F*	*Significant*	*Pr > F*	*Significant*	*Pr > F*	*Significant*	*Pr > F*	*Significant*
1-Butanol	<0.0001	Yes	0,298	No	<0.0001	Yes	0,146	No	0,412	No	<0.0001	Yes
Isoamyl alcohol	0,214	No	0,000	Yes	<0.0001	Yes	0,010	Yes	0,143	No	<0.0001	Yes
1-Pentanol	0,042	Yes	0,001	Yes	<0.0001	Yes	0,001	Yes	0,021	Yes	0,000	Yes
Phenylethyl alcohol	0,658	No	0,005	Yes	0,097	No	0,036	Yes	<0.0001	Yes	<0.0001	Yes
Methionol	0,529	No	<0.0001	Yes	<0.0001	Yes	0,005	Yes	<0.0001	Yes	<0.0001	Yes
1-Hexanol	0,292	No	<0.0001	Yes	<0.0001	Yes	0,369	No	0,008	Yes	0,028	Yes
trans-3-Hexen-1-ol	0,063	No	0,000	Yes	<0.0001	Yes	0,258	No	0,794	No	0,681	No
cis-3-Hexen-1-ol	0,001	Yes	0,285	No	<0.0001	Yes	0,996	No	<0.0001	Yes	0,008	Yes
cis-2-hexen-1-ol	0,992	No	<0.0001	Yes	<0.0001	Yes	0,710	No	<0.0001	Yes	<0.0001	Yes
Isoamyl acetate	0,164	No	0,007	Yes	0,012	Yes	0,056	No	0,496	No	0,387	No
n-Hexyl acetate	0,881	No	<0.0001	Yes	<0.0001	Yes	0,754	No	<0.0001	Yes	<0.0001	Yes
2-Phenethyl acetate	0,160	No	0,005	Yes	<0.0001	Yes	<0.0001	Yes	0,220	No	0,000	Yes
Ethyl-2-methylbutanoate	0,088	No	<0.0001	Yes	<0.0001	Yes	0,271	No	<0.0001	Yes	<0.0001	Yes
Ethyl-3-methylbutanoate	0,203	No	<0.0001	Yes	<0.0001	Yes	0,235	No	<0.0001	Yes	<0.0001	Yes
Ethyl lactate	0,010	Yes	<0.0001	Yes	<0.0001	Yes	0,129	No	<0.0001	Yes	<0.0001	Yes
Ethyl butanoate	0,455	No	<0.0001	Yes	<0.0001	Yes	0,326	No	0,015	Yes	<0.0001	Yes
Ethyl-3-hydroxybutanoate	0,048	Yes	<0.0001	Yes	<0.0001	Yes	0,102	No	<0.0001	Yes	<0.0001	Yes
Ethyl hexanoate	0,225	No	<0.0001	Yes	<0.0001	Yes	0,390	No	0,920	No	<0.0001	Yes
ethyl octanoate	0,124	No	<0.0001	Yes	<0.0001	Yes	0,454	No	<0.0001	Yes	<0.0001	Yes
Ethyl decanoate	0,254	No	<0.0001	Yes	<0.0001	Yes	0,799	No	<0.0001	Yes	<0.0001	Yes
Ethyl cinnamate	0,071	No	0,427	No	0,267	No	0,627	No	0,217	No	0,442	No
3-Methylbutanoic acid	0,239	No	<0.0001	Yes	<0.0001	Yes	0,058	No	0,076	No	0,000	Yes
Octanoic acid	0,207	No	0,000	Yes	<0.0001	Yes	0,767	No	<0.0001	Yes	<0.0001	Yes
Hexanoic acid	0,982	No	<0.0001	Yes	<0.0001	Yes	0,939	No	<0.0001	Yes	<0.0001	Yes
trans-Linaloloxide	0,160	No	<0.0001	Yes	<0.0001	Yes	0,326	No	<0.0001	Yes	<0.0001	Yes
cis-Linaloloxide	0,272	No	<0.0001	Yes	<0.0001	Yes	0,088	No	<0.0001	Yes	<0.0001	Yes
Linalool	<0.0001	Yes	<0.0001	Yes	<0.0001	Yes	0,000	Yes	0,008	Yes	<0.0001	Yes
α-Terpineol	0,000	Yes	<0.0001	Yes	<0.0001	Yes	0,000	Yes	<0.0001	Yes	<0.0001	Yes
β-Citronellol	<0.0001	Yes	0,334	No	<0.0001	Yes	0,000	Yes	0,004	Yes	<0.0001	Yes
Geraniol	0,055	No	0,002	Yes	<0.0001	Yes	<0.0001	Yes	0,015	Yes	<0.0001	Yes
α-Phellandrene	0,296	No	0,002	Yes	<0.0001	Yes	0,049	Yes	0,799	No	<0.0001	Yes
α-Terpinen	0,069	No	<0.0001	Yes	<0.0001	Yes	0,739	No	<0.0001	Yes	<0.0001	Yes
1,4-cineole	0,473	No	<0.0001	Yes	<0.0001	Yes	0,004	Yes	0,001	Yes	<0.0001	Yes
Limonene	0,019	Yes	0,000	Yes	<0.0001	Yes	0,353	No	<0.0001	Yes	<0.0001	Yes
1,8-Cineole	0,179	No	<0.0001	Yes	<0.0001	Yes	0,079	No	<0.0001	Yes	<0.0001	Yes
p-Cymene	0,007	Yes	0,014	Yes	<0.0001	Yes	0,638	No	<0.0001	Yes	<0.0001	Yes
Terpinolene	0,047	Yes	<0.0001	Yes	<0.0001	Yes	0,639	No	<0.0001	Yes	<0.0001	Yes
β-Damascenone	0,021	Yes	<0.0001	Yes	<0.0001	Yes	0,019	Yes	<0.0001	Yes	<0.0001	Yes
Vitispirane	0,001	Yes	0,188	No	<0.0001	Yes	<0.0001	Yes	0,231	No	<0.0001	Yes
TPB	0,000	Yes	0,276	No	<0.0001	Yes	<0.0001	Yes	0,310	No	<0.0001	Yes
TDN	0,001	Yes	0,133	No	<0.0001	Yes	<0.0001	Yes	0,002	Yes	<0.0001	Yes
3-Oxo-α-ionol	0,776	No	<0.0001	Yes	<0.0001	Yes	0,761	No	<0.0001	Yes	<0.0001	Yes
3-Hydroxy-β-damascone	0,966	No	<0.0001	Yes	<0.0001	Yes	0,060	No	<0.0001	Yes	<0.0001	Yes
Furfural	0,989	No	<0.0001	Yes	<0.0001	Yes	0,622	No	<0.0001	Yes	<0.0001	Yes
Benzaldehyde	0,018	Yes	0,395	No	<0.0001	Yes	0,922	No	<0.0001	Yes	<0.0001	Yes
Benzyl alcohol	0,564	No	<0.0001	Yes	<0.0001	Yes	1,000	No	<0.0001	Yes	<0.0001	Yes
Vanillin	0,019	Yes	<0.0001	Yes	<0.0001	Yes	0,005	Yes	0,045	Yes	0,000	Yes
Methyl-vanillate	0,067	No	<0.0001	Yes	<0.0001	Yes	0,000	Yes	0,000	Yes	<0.0001	Yes
Ethyl-vanillate	0,011	Yes	0,000	Yes	<0.0001	Yes	0,096	No	0,025	Yes	<0.0001	Yes
Methyl salycilate	0,072	No	0,001	Yes	<0.0001	Yes	0,002	Yes	0,981	No	<0.0001	Yes
Eugenol	0,097	No	<0.0001	Yes	<0.0001	Yes	0,723	No	<0.0001	Yes	<0.0001	Yes
2,6-Dimethoxy-phenol	0,036	Yes	0,001	Yes	<0.0001	Yes	0,752	No	<0.0001	Yes	<0.0001	Yes
γ-Nonalactone	0,001	Yes	0,064	No	0,000	Yes	<0.0001	Yes	0,080	No	<0.0001	Yes

Appendix 1.3.2.4. Minimum (min) and Maximum (max) compounds content (μg/) in Corvina and Corvinone wines within the three vintages

	Corvina									**Corvinone**								
	2017			**2018**			**2019**			**2017**			**2018**			**2019**		
	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
Alcohols	233739.47	212905.04	250291.27	205718.76	179061.89	246012.75	179734.01	138135.98	265080.10	245945.48	236567.50	261422.90	225811.29	189932.39	257141.73	217698.84	145429.16	263046.59
1-Butanol	142.00	114.47	175.08	154.98	124.84	188.23	145.99	97.56	210.88	149.98	79.28	218.36	147.04	134.60	161.95	130.22	103.32	160.52
Isoamyl alcool	215216.08	191793.55	230378.30	188592.28	165199.75	225462.96	165764.52	128888.61	247747.69	225193.39	216262.21	241045.36	207489.93	175315.82	234199.13	203312.47	136008.64	244949.17
1-Pentanol	55.62	51.83	60.36	58.45	46.14	71.15	72.06	52.32	103.36	91.58	61.88	109.69	95.84	74.71	113.80	94.48	58.89	114.79
Phenylethyl Alcohol	18078.40	13471.60	22210.82	16581.11	13296.63	19965.91	13677.71	8899.61	16952.62	20219.09	17834.93	24419.09	17599.17	13795.39	22308.34	13969.52	9103.25	17544.39
Methionol	247.37	83.34	390.68	331.93	183.73	461.46	73.71	33.53	168.22	291.44	166.15	432.10	479.32	320.42	713.27	192.16	64.34	329.27
C_6 alcohols	2425.03	2425.03	2425.03	1761.80	1633.60	1984.39	1644.82	1428.57	1796.26	2567.45	2194.54	3232.09	2709.96	2137.03	3062.53	2240.82	1799.68	2796.74
1-Hexanol	1975.11	1536.22	2632.54	1600.48	1498.87	1817.79	1493.01	1312.84	1666.84	2456.68	2121.25	2978.93	2618.53	2061.63	2970.21	2178.95	1744.53	2720.05
trans-3-Hexen-1-ol	16.38	10.94	25.32	13.15	11.25	14.34	12.11	11.56	12.77	22.85	17.94	32.47	37.02	21.38	57.17	22.06	16.22	29.07
cis-3-Hexen-1-ol	169.79	70.58	325.25	135.09	96.43	184.72	137.06	101.50	192.21	41.42	33.31	52.25	40.32	30.70	50.61	34.26	30.72	40.49
cis-2-Hexen-1-ol	5.16	3.36	7.55	13.08	12.37	13.75	2.63	2.33	2.74	7.19	4.84	10.83	14.10	13.42	15.78	5.54	3.37	7.14
Acetate esters	446.48	268.60	644.21	467.52	196.64	836.99	240.11	159.80	416.95	282.46	172.12	343.62	585.50	352.67	1056.46	329.02	211.76	525.17
Isoamyl acetate	401.52	238.13	583.14	438.26	175.66	794.95	214.96	136.89	382.65	243.60	137.69	305.45	550.32	328.05	1000.38	298.20	190.71	481.06
2-Phenethyl acetate	29.49	18.47	43.46	25.75	19.84	34.10	22.51	18.86	29.36	25.17	21.18	30.90	27.60	22.60	39.95	26.22	19.20	36.41
n-Hexyl acetate	15.48	12.01	19.54	3.51	0.89	7.94	2.64	1.82	4.94	13.69	10.45	15.58	7.57	1.59	16.13	4.60	1.72	7.69
Branched-chain fatty acisd ethyl esters	15.49	9.85	20.55	6.85	5.69	10.66	12.40	8.56	15.35	12.98	10.26	14.37	6.50	4.96	7.93	10.07	8.26	11.94
Ethyl-2-methylbutanoate	6.97	4.38	9.36	3.48	2.84	4.79	5.93	4.27	7.19	6.37	5.48	7.38	3.32	2.39	4.12	5.13	4.54	6.25
Ethyl-3-methylbutanoate	8.52	5.47	11.23	3.38	2.40	5.87	6.46	4.29	8.16	6.61	4.78	8.22	3.17	2.42	3.93	4.94	3.72	5.69
Fatty acids ethyl esters	1464.64	1110.48	1758.64	1098.90	679.68	1492.44	818.48	554.83	1047.89	1402.49	1011.10	1820.36	1232.02	1054.31	1515.32	891.29	752.73	1026.55
Ethyl lactate	661.00	332.70	916.16	355.00	105.53	651.45	339.22	147.72	554.52	568.36	317.00	765.32	369.41	143.89	828.09	223.97	104.46	289.22
Ethyl butanoate	162.71	110.60	202.75	157.67	125.79	193.45	102.87	93.24	118.50	151.49	112.20	202.14	174.16	141.79	191.09	126.71	114.24	142.54
Ethyl 3-hydroxybutyrate	108.55	46.69	171.65	121.32	38.90	150.94	57.81	27.91	112.48	134.94	60.02	178.08	145.13	124.24	170.86	82.23	31.78	120.99
Ethyl hexanoate	332.76	214.61	475.74	311.79	273.31	354.01	222.02	164.89	338.20	335.86	255.07	421.40	363.00	276.81	427.51	343.23	232.67	401.27
Ethyl octanoate	159.30	81.12	230.29	128.54	108.37	145.32	82.05	43.15	137.44	169.01	124.40	216.72	147.19	113.45	185.56	98.66	66.73	121.82

	Corvina									Corvinone								
	2017			2018			2019			2017			2018			2019		
	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
Ethyl decanoate	39.85	31.39	54.76	24.32	18.88	29.18	13.88	8.76	23.58	42.36	29.80	56.52	32.99	22.69	48.65	16.09	13.45	18.97
Ethyl cinnamate	0.47	0.21	0.84	0.26	0.07	0.52	0.63	0.18	1.49	0.47	0.26	0.68	0.13	0.03	0.29	0.41	0.24	0.62
Fatty acids	3457.32	2676.41	4550.70	5496.51	5102.52	5894.99	3466.71	2350.66	4607.56	3732.59	3152.55	4263.13	6450.79	5456.95	7291.07	4829.74	3489.65	5697.97
3-Methylbutanoic acid	346.59	319.78	375.14	390.12	354.00	429.14	307.01	245.32	420.74	381.35	320.71	447.30	418.63	381.43	513.52	383.50	313.74	468.16
Hexanoic acid	1827.52	1431.17	2426.55	1857.12	1566.74	2110.10	2132.49	1384.53	2856.20	1986.20	1625.77	2315.20	2457.90	1680.13	3455.42	3038.42	2050.66	3898.54
Octanoic acid	1283.21	903.16	1749.01	3249.26	2948.25	3523.98	1027.21	696.45	1425.18	1365.04	1156.95	1627.22	3574.26	3385.16	3799.37	1407.82	1096.02	1934.73
Terpenes	54.82	33.03	72.42	40.97	35.10	50.57	42.87	34.90	50.73	41.04	30.07	49.63	37.05	33.03	41.42	40.43	31.88	45.25
trans-Linaloloxide	1.26	0.62	2.33	0.00	0.00	0.00	2.06	0.92	3.36	1.26	0.54	2.43	0.00	0.00	0.00	1.07	0.75	1.43
cis-Linaloloxide	1.40	0.37	2.06	0.00	0.00	0.00	3.09	1.62	5.34	0.96	0.16	1.76	0.00	0.00	0.00	0.88	0.00	1.72
Linalool	19.67	9.39	33.77	10.15	6.83	15.65	9.74	3.56	16.44	13.12	8.38	22.56	8.38	5.63	13.55	11.99	9.02	14.14
α-Terpineol	6.03	2.71	11.18	1.69	0.75	3.27	3.16	1.11	5.50	4.01	2.03	7.41	1.45	0.61	2.72	4.16	2.96	6.21
β-Citronellol	11.45	9.24	14.86	14.37	6.73	26.71	13.20	5.85	17.63	8.96	5.59	13.19	11.47	8.20	13.20	11.46	9.43	12.80
Geraniol	12.31	7.77	19.28	10.95	6.89	13.94	8.50	7.15	9.22	11.09	8.46	14.24	11.74	6.45	16.06	8.36	4.92	12.66
α-phellandrene	0.97	0.50	1.84	2.07	1.45	2.90	0.84	0.46	1.64	0.65	0.52	0.73	2.68	2.15	3.17	0.62	0.47	0.82
α-terpinen	0.15	0.07	0.23	0.23	0.10	0.42	0.35	0.16	0.74	0.07	0.05	0.10	0.11	0.05	0.14	0.32	0.24	0.54
1,4-Cineol	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Limonene	0.51	0.30	0.80	0.59	0.34	0.75	0.98	0.36	1.63	0.34	0.26	0.38	0.58	0.33	1.04	1.14	0.80	1.83
1,8-Cineol	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
p-Cymene	0.31	0.21	0.50	0.38	0.28	0.59	0.94	0.28	3.03	0.16	0.14	0.20	0.17	0.08	0.24	0.43	0.29	0.56
Terpinolene	0.49	0.27	0.85	0.55	0.36	0.81	0.00	0.00	0.00	0.28	0.17	0.36	0.47	0.21	0.84	0.00	0.00	0.00
Norisoprenoids	19.54	16.11	22.66	21.27	5.17	77.91	14.57	8.70	24.82	35.66	21.77	52.69	29.33	7.12	98.86	22.22	17.04	34.62
β-Damascenone	4.63	2.61	6.25	1.24	0.23	2.36	2.92	1.34	4.32	6.62	4.33	9.89	2.27	0.37	3.45	6.13	3.32	7.93
3-Hydroxy-β-damascone	0.23	0.19	0.25	0.20	0.13	0.27	0.36	0.32	0.40	0.14	0.10	0.21	0.14	0.08	0.18	0.22	0.12	0.32
3-Oxo-α-ionol	2.62	2.15	3.70	2.40	1.69	2.66	6.83	4.70	9.67	2.88	2.26	3.61	1.96	1.42	3.14	5.75	3.41	7.65
Vitispirane	7.44	5.18	8.38	5.45	0.33	25.04	2.36	0.38	10.4	16.85	9.56	25.76	4.80	0.37	20.60	9.17	5.08	18.17
TPB	0.08	0.03	0.11	0.14	0.02	0.58	0.04	0.00	0.07	0.09	0.05	0.12	0.09	0.01	0.34	0.05	0.03	0.08
TDN	4.54	2.55	7.03	11.85	0.77	49.20	0.86	0.09	2.15	9.08	4.39	18.27	20.06	2.29	72.57	0.91	0.50	1.80
Benzenoids and others	287.25	237.14	338.71	420.08	289.17	557.74	568.01	355.08	907.90	179.78	113.76	215.06	289.46	257.74	327.82	294.59	173.81	451.27
Furfural	2.23	1.86	2.81	1.03	0.94	1.11	0.92	0.00	1.45	2.62	1.87	3.35	1.15	1.02	1.27	1.12	0.34	1.54
Benzaldehyde	19.47	14.82	27.77	20.70	15.09	32.45	20.68	4.32	48.02	15.09	14.78	15.35	15.93	14.18	18.17	5.46	3.92	7.75
Benzyl Alcohol	129.69	91.04	170.53	219.68	105.57	345.70	245.19	162.42	332.30	14.40	8.29	22.16	41.68	18.52	78.66	54.10	43.82	65.07
Vanillin	8.90	6.97	12.96	5.27	4.38	6.19	10.48	4.26	14.96	6.35	5.37	8.60	5.62	4.47	7.93	8.48	5.71	10.21
Methyl-vanillate	8.42	5.65	9.69	7.72	7.45	7.89	11.44	9.00	15.79	13.56	10.51	22.29	16.10	9.83	25.95	20.81	14.86	28.24
Ethyl-vanillate	107.44	84.14	147.76	153.39	131.90	197.30	261.68	113.76	588.00	120.46	63.62	157.07	199.71	139.22	224.09	192.07	77.60	346.50

	Corvina									Corvinone								
	2017			2018			2019			2017			2018			2019		
	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
Methyl-salycilate	0.32	0.24	0.39	0.56	0.21	1.68	0.16	0.00	0.40	0.47	0.33	0.63	0.34	0.25	0.47	0.45	0.00	1.41
2,6-Dimethoxy-Phenol	5.22	4.78	5.73	7.35	6.41	9.36	10.23	9.73	10.68	5.75	4.62	6.53	7.43	6.51	8.04	10.19	8.57	11.42
Eugenol	5.57	2.90	8.39	4.39	2.30	5.21	7.22	4.19	11.04	1.09	0.90	1.33	1.50	0.83	2.16	1.91	1.16	2.92
Others	13.72	9.86	17.75	15.17	12.41	17.86	11.27	8.32	12.96	19.77	6.58	44.18	17.08	11.80	29.14	15.26	8.81	28.29
γ-Nonalactone	13.72	9.86	17.75	15.17	12.41	17.86	11.27	8.32	12.96	19.77	6.58	44.18	17.08	11.80	29.14	15.26	8.81	28.29

Appendix 1.3.2.5. Significantly different compounds and classes of compounds between withered Corvina and Corvinone during the three vintages according to Mann-Whitney(α=0.05)

	2017	2018	2019
Alcohols			
1-Butanol	0.860	0.512	0.361
Isoamyl alcohol	0.118	**0.035**	0.067
1-Pentanol	**<0.0001**	**0.002**	**0.007**
Phenylethyl alcohol	0.193	**0.034**	0.683
Methionol	0.631	0.678	**0.000**
C6 Alcohols			
1-Hexanol	**0.005**	0.135	**<0.0001**
trans-3-Hexen-1-ol	**0.004**	**0.000**	**<0.0001**
cis-3-Hexen-1-ol	**<0.0001**	**<0.0001**	**<0.0001**
cis-2-Hexen-1-ol	**0.004**	0.432	**<0.0001**
Acetate esters			
Isoamyl acetate	**0.008**	0.012	**0.019**
2-Phenethyl acetate	0.212	0.34	**0.008**
n-Hexyl acetate	0.322	**0.0041**	0.389
Ethyl esters			
Ethyl lactate	0.595	0.653	0.098
Ethyl butanoate	0.347	0.136	**<0.0001**
Ethyl 3-hydroxybutanoate	0.212	0.675	0.067
Ethyl hexanoate	0.705	0.125	**<0.0001**
Ethyl octanoate	0.820	0.765	0.148
Ethyl decanoate	0.595	0.234	0.074
Ethyl cinnamate	0.991	0.678	0.942
Branched-chain fatty acid ethyl esters			
Ethyl-2-methylbutanoate	0.929	**<0.0001**	**0.038**
Ethyl 3-methylbutanoate	0.067	**<0.0001**	**0.003**
Organic acid			
3-Methylbutanoic acid	0.095	**0.01**	**0.007**
Hexanoic acid	0.980	0.435	**0.001**
Octanoic acid	0.820	0.673	**0.004**
Linear terpens			
Linalol	0.067	0.156	0.395
beta citronellol	**0.017**	0.211	0.202
Geraniol	0.280	0.341	0.587
limonene	**0.042**	**0.001**	0.705
Nerol			
Cyclic terpens			
α-Terpineol	0.067	0.442	0.350
trans-Linaloloxide	**0.042**		**0.000**
cis-Linaloloxide	0.890		**<0.0001**
α-Phellandrene	**0.010**	**<0.0001**	0.157
α-Terpinen	**0.001**	**<0.0001**	0.798
1,4-Cineol	**<0.0001**	0.121	
1,8-Cineol	**0.015**	**0.040**	0.444
p-Cymene	**<0.0001**	**<0.0001**	0.418
Terpinolene	**0.024**	**0.002**	0.775
p-Cymenene			
Norisoprenoids			
β-damascenone	0.061	**0.005**	**<0.0001**
3-hydroxy-β-damascone	**<0.0001**	0.066	**<0.0001**
Vitispirane	**<0.0001**	0.116	**<0.0001**
TPB	0.614	0.512	0.838
TDN	**0.008**	0.935	0.325
3-Oxo-alpha-ionol	0.180	**<0.0001**	0.145
Benzenoids			
Furfural	0.066	0.560	0.183
Benzaldehyde	**0.001**	**0.001**	**0.010**
Benzyl Alcohol	**<0.0001**	**<0.0001**	**<0.0001**
Vanillin	0.060	**0.004**	**0.000**
Methyl-vanillate	**<0.0001**	**<0.0001**	**<0.0001**
Ethyl-vanillate	0.322	**<0.0001**	0.267
Methyl-salycilate	**0.000**	0.350	0.373
Eugenol	**<0.0001**	**<0.0001**	**<0.0001**
2-6-Dimethoxy-phenol	0.595	0.362	1.000
Others			
γ-Nonalactone	0.322	**0.001**	0.061

Appendix 1.3.2.6. OAVs of aroma active compounds in single vineyards wines

	2017					2018					2019				
	v1	v2	v3	v4	v5	v1	v2	v3	v4	v5	v1	v2	v3	v4	v5
Corvina															
Ethyl hexanoate	42,92	59,26	60,25	91,38	76,17	95,14	73,30	110,5	63,31	55,33	32,98	67,64	46,72	41,54	33,14
β-damascenone	52,10	124,00	92,40	74,73	123,93	23,60	47,13	23,07	4,53	25,47	26,87	86,47	65,73	46,60	66,47
Isoamyl acetate	7,95	7,94	19,44	13,83	15,94	23,12	36,83	47,67	46,97	27,00	4,59	12,76	7,29	4,56	6,63
Ethyl octanoate	5,79	11,40	10,39	16,34	13,60	19,57	11,16	19,13	9,64	9,32	3,66	9,82	5,53	7,21	3,08
Isoamyl alcohol	6,39	7,13	7,68	7,01	7,16	7,94	7,44	8,34	10,17	8,68	4,88	8,26	5,22	4,97	4,30
Ethyl butanoate	5,53	8,58	8,07	8,03	9,74	7,35	6,81	9,66	7,26	5,64	5,09	5,93	5,07	4,97	4,66
Octanoic acid	1,81	2,38	2,04	3,55	3,32	10,10	9,89	10,74	8,54	7,59	3,26	5,71	4,80	4,78	2,77
Hexanoic acid	3,41	3,92	3,59	5,88	5,40	6,71	6,76	7,56	4,18	4,29	1,99	3,39	2,73	2,46	1,66
Ethyl 3-methylbutanoate	3,60	1,82	3,74	2,60	2,24	1,95	1,28	1,95	1,84	1,71	2,63	1,43	2,72	2,11	1,88
TPB	0,63	2,75	2,63	0,83	2,83	0,48	0,59	1,10	0,43	14,59	0,00	1,07	1,70	0,84	2,69
TDN	1,27	1,84	3,51	1,59	3,14	0,16	0,25	0,49	0,19	12,52	0,05	0,35	0,49	0,19	1,07
3-Methylbutanoic acid	1,37	1,34	1,44	1,52	1,29	2,32	1,65	2,03	2,41	1,71	1,68	1,30	1,09	0,98	1,08
Phenylethyl alcohol	1,49	0,96	1,39	1,06	1,11	1,33	1,16	1,41	1,91	1,47	0,97	1,21	0,99	1,08	0,64
cis-3-Hexen-1-ol	0,81	0,34	0,31	0,18	0,46	1,16	1,65	1,35	0,87	0,56	0,42	0,48	0,27	0,25	0,29
Corvinone															
β-damascenone	96,40	166,80	209,47	84,67	121,20	46,07	54,80	49,93	7,33	68,93	66,40	137,73	158,67	118,00	131,93
Ethyl hexanoate	52,88	78,47	58,75	66,12	82,25	87,55	58,25	81,63	55,30	61,20	69,71	80,25	70,38	76,36	46,53
Isoamyl acetate	6,15	10,18	4,51	9,68	10,10	27,52	29,14	29,72	44,05	17,74	11,14	9,04	6,36	16,04	7,12
Ethyl octanoate	9,37	15,46	10,52	10,94	15,53	15,14	11,88	13,40	10,22	9,63	5,26	8,45	8,05	8,70	4,77
Isoamyl alcohol	7,22	8,03	7,74	7,14	7,26	7,80	7,22	6,93	8,27	7,86	7,44	8,16	7,31	6,44	4,53
Ethyl butanoate	5,82	9,42	6,76	6,30	9,77	8,37	6,13	8,31	5,26	5,24	6,02	6,14	6,79	7,13	5,91
Octanoic acid	2,31	3,21	2,54	2,42	3,26	9,33	9,10	10,31	8,16	8,29	7,80	6,20	5,62	6,66	4,10
Hexanoic acid	4,03	5,26	4,55	4,47	5,41	6,01	5,57	7,37	4,41	5,53	3,54	4,61	2,83	3,17	2,61
TDN	2,20	4,51	2,57	4,30	9,14	0,21	0,20	0,18	1,11	10,30	0,33	0,40	0,40	0,25	0,90
TPB	1,17	2,75	1,83	2,25	3,08	0,55	0,27	0,40	1,70	8,38	0,79	1,14	1,23	0,96	2,02
Ethyl 3-methylbutanoate	2,33	2,17	1,51	2,23	2,53	1,56	1,17	1,13	1,23	1,21	1,90	1,67	1,24	1,64	1,79
3-Methylbutanoic acid	1,58	1,44	1,80	1,60	1,21	1,84	1,50	1,40	2,14	1,37	1,25	1,87	1,67	1,50	1,37
Phenylethyl alcohol	1,45	1,40	1,35	1,65	1,26	1,32	1,32	1,02	1,53	1,28	0,98	1,25	0,91	1,20	0,65

Appendix 1.3.2.7. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2017 Corvina withered wines										
	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	114.47	2.19	175.08	3.12	157.53	5.36	126.67	10.98	136.27	2.01
Isoamyl alcool	191794	1161	213993	16880	230378	1441	213635	16823	226281	13495
1-Pentanol	56.55	1.09	57.13	0.15	52.22	0.40	51.83	3.37	60.36	3.07
Phenylethyl Alcohol	20857.13	985.08	13471.60	1494.64	19422.32	494.39	22210.82	1416.52	14430.13	799.11
Methionol	83.34	5.75	390.68	39.77	280.91	33.91	186.95	2.63	294.97	42.13
C_6 alcohols										
1-Hexanol	2078.52	86.80	1536.22	9.93	1713.64	31.23	2632.54	186.58	1914.66	9.96
trans-3-Hexen-1-ol	16.23	0.04	10.94	0.02	15.69	0.00	25.32	1.28	13.73	0.35
cis-3-Hexen-1-ol	325.25	5.36	136.34	8.46	125.73	23.65	70.58	1.95	191.07	18.93
cis-2-Hexen-1-ol	5.03	0.06	3.36	0.61	5.02	0.41	7.55	0.56	4.85	0.10
Acetate esters										
Isoamyl acetate	238.64	8.71	238.125	37.345	583.135	36.165	447.85	137.18	499.84	30.7
2-Phenethyl acetate	27.665	0.855	18.47	0.96	43.46	0.13	33.455	6.765	24.4	0.29
n-Hexyl acetate	13.005	0.195	12.005	0.905	17.61	1.68	19.535	3.235	15.225	0.795
Branched-chain fatty acisd ethyl esters										
Ethyl-2-methylbutanoate	9.36	0.03	4.38	0.02	9.325	0.285	6.405	1.355	5.4	0.2
Ethyl 3-methylbutanoate	10.785	0.425	5.465	0.995	11.225	0.485	8.01	0.8	7.115	0.435
Fatty acids ethyl esters										
Ethyl lactate	619.405	24.025	651.63	45.87	916.155	87.555	332.7	31.99	785.12	56.06
Ethyl butanoate	110.595	0.475	171.64	19.13	161.475	0.425	167.09	0.03	202.745	3.875
Ethyl 3-hydroxybutanoate	46.685	1.185	139.54	15.84	110.47	6.78	74.41	2.14	171.65	12.83
Ethyl hexanoate	214.61	14.99	296.28	27.95	301.26	15.44	475.735	13.595	375.9	3.04
Ethyl octanoate	81.115	9.325	159.54	16.92	145.39	7.75	230.285	15.515	180.19	2.34
Ethyl decanoate	37.86	2.19	32.98	2.16	31.39	2.03	54.76	3.03	42.30	3.67
Ethyl cinnamate	0.21	0.13	0.84	0.10	0.35	0.06	0.21	0.00	0.74	0.19
Fatty acids										
3-Methylbutanoic acid	342.09	17.18	335.78	16.57	360.17	9.20	375.14	44.78	319.78	10.38
Hexanoic acid	1431.17	28.33	1645.86	148.64	1509.52	45.77	2426.55	107.27	2124.50	49.38
Octanoic acid	903.16	5.21	1189.59	125.63	1018.16	48.31	1749.01	50.13	1556.15	17.56
Terpenes										
trans-Linaloloxide	2.33	0.24	0.91	0.23	0.86	0.11	0.62	0.42	1.60	0.17
cis-Linaloloxide	2.06	0.11	1.54	0.03	1.35	0.03	0.37	0.01	1.67	0.15
Linalool	15.87	0.09	21.29	0.93	18.05	0.07	9.39	2.08	33.77	1.41
α-Terpineol	5.29	0.23	6.21	0.06	4.77	0.07	2.71	0.05	11.18	0.18
β-Citronellol	13.16	0.46	14.86	0.18	9.59	0.18	10.41	0.56	9.24	0.11
Geraniol	10.57	0.64	19.28	0.05	11.81	0.65	7.77	0.10	12.13	1.03
α-Phellandrene	0.93	0.12	1.84	1.84	0.50	0.50	0.73	0.73	0.86	0.86
α-Terpinen	0.23	0.01	0.17	0.00	0.11	0.07	0.07	0.01	0.15	0.01
1,4-Cineol	0.02	0.00	0.01	0.01	0.02	0.02	0.00	0.00	0.01	0.01
Limonene	0.49	0.00	0.80	0.80	0.30	0.30	0.33	0.33	0.62	0.62

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1,8-Cineol	0.02	0.00	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
p-Cymene	0.50	0.04	0.29	0.02	0.26	0.14	0.21	0.03	0.32	0.07
Norisoprenoids										
β-Damascenone	2.61	0.30	6.20	1.01	4.62	0.33	3.46	0.30	6.25	0.44
3-Hydroxy-β-damascone	0.25	0.01	0.19	0.03	0.23	0.02	0.23	0.01	0.24	0.03
3-Oxo-α-ionol	2.31	0.08	3.70	0.03	2.15	0.31	2.58	0.04	2.38	0.03
Vitispirane	8.38	0.97	5.18	1.10	8.14	0.45	8.12	0.91	7.40	1.49
TPB	0.03	0.01	0.11	0.01	0.11	0.01	0.03	0.01	0.11	0.01
TDN	2.55	0.57	3.69	0.53	7.03	0.35	3.18	0.47	6.28	1.24
Benzenoids and others										
Furfural	2.81	0.06	2.23	0.05	1.93	0.01	1.86	0.11	2.33	0.07
Benzaldehyde	27.77	2.35	23.19	1.70	15.94	0.14	14.82	0.08	15.64	0.04
Benzyl Alcohol	127.17	4.73	170.53	13.79	120.16	10.31	91.04	5.75	139.56	5.64
Vanillin	12.96	0.39	6.97	0.56	8.13	1.50	6.98	2.13	9.48	0.48
Methyl-vanillate	9.23	0.33	5.65	0.09	8.78	2.95	9.69	0.07	8.75	0.15
Ethyl-vanillate	147.76	6.33	84.14	2.54	87.82	2.21	104.39	10.88	113.09	5.60
Methyl-salycilate	0.39	0.06	0.38	0.05	0.28	0.04	0.24	0.02	0.30	0.03
2,6-Dimethoxy-Phenol	5.05	0.43	5.30	0.05	4.78	0.18	5.24	0.75	5.73	0.01
Eugenol	5.58	0.30	8.39	0.11	4.54	0.38	2.90	0.10	6.46	0.06
Others										
γ-Nonalactone	16.34	0.79	17.75	0.76	10.34	3.61	9.86	3.35	14.31	0.60

Appendix 1.3.2.8. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2018 Corvina withered wines

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	124.84	4.73	145.38	5.13	188.23	25.15	148.91	8.39	167.54	21.09
Isoamyl alcool	225462.96	8565.71	175376.47	5715.49	165199.75	16508.59	195138.84	10749.82	181783.38	8644.25
1-Pentanol	62.00	0.90	71.15	3.97	61.50	2.16	46.14	3.94	51.48	6.54
Phenylethyl Alcohol	19916.03	1055.00	13300.70	437.39	13296.63	2287.17	19965.91	1541.67	16426.30	714.47
Methionol	446.93	46.67	461.46	33.45	315.79	35.03	183.73	11.55	251.76	34.00
C_6 alcohols										
1-Hexanol	1646.81	43.98	1498.87	148.12	1510.09	279.34	1817.79	52.31	1528.85	111.42
trans-3-Hexen-1-ol	13.15	0.04	11.25	0.68	13.32	1.63	13.69	0.33	14.34	0.40
cis-3-Hexen-1-ol	184.72	3.04	147.54	6.53	96.43	18.59	139.92	1.05	106.82	10.94
cis-2-Hexen-1-ol	12.37	0.34	13.63	0.29	13.75	0.96	13.00	0.10	12.64	0.37
Acetate esters										
Isoamyl acetate	175.66	19.46	301.56	28.02	794.95	66.28	399.58	14.63	519.55	79.23
2-Phenethyl acetate	0.89	0.10	1.42	0.21	7.94	0.82	2.68	0.44	4.62	0.51
n-Hexyl acetate	20.10	1.12	19.84	0.83	34.10	4.35	27.79	1.46	26.95	1.02
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	3.24	0.06	2.84	0.26	3.05	0.39	3.48	0.26	4.79	0.57
Ethyl 3-methylbutanoate	2.66	0.06	2.85	0.11	3.09	0.34	2.40	0.07	5.87	0.32
Fatty acids ethyl esters										
Ethyl lactate	192.45	25.91	450.87	42.46	374.71	60.59	105.53	5.76	651.45	60.38
Ethyl butanoate	141.74	7.37	152.47	5.35	193.45	15.80	125.79	11.22	174.92	18.74
Ethyl 3-hydroxybutanoate	150.94	3.03	140.30	12.15	131.42	3.05	38.90	1.62	145.04	14.82
Ethyl hexanoate	326.83	1.61	273.31	7.17	322.64	51.42	282.14	43.89	354.01	37.01
Ethyl octanoate	145.32	7.12	123.88	12.86	127.38	30.61	108.37	44.93	137.75	23.29
Ethyl decanoate	27.89	1.18	24.73	3.15	20.91	6.47	18.88	4.02	29.18	5.10
Ethyl cinnamate	0.40	0.02	0.52	0.07	0.24	0.03	0.07	0.00	0.09	0.01
Fatty acids										
3-Methylbutanoic acid	429.14	18.40	386.64	21.57	354.00	37.29	390.94	7.13	389.89	45.16
Hexanoic acid	1917.14	62.62	1566.74	74.91	2110.10	284.95	1654.41	36.45	2037.21	84.23
Octanoic acid	3523.98	110.77	3149.14	102.54	2948.25	452.94	3157.05	79.81	3467.89	58.81
Terpenes										
trans-Linaloloxide										
cis-Linaloloxide										
Linalool	8.65	0.60	11.55	0.71	6.83	1.02	8.08	0.04	15.65	0.68
α-Terpineol	0.75	0.04	1.72	0.11	1.16	0.02	1.54	0.15	3.27	0.26
β-Citronellol	26.71	1.44	13.11	1.21	11.55	2.07	13.77	0.22	6.73	1.05
Geraniol	11.79	0.24	13.94	0.86	11.40	1.19	10.73	0.23	6.89	0.80
α-Phellandrene	1.45	0.05	1.76	0.27	2.52	0.13	2.90	0.09	1.70	0.01
α-Terpinen	0.19	3E-17	0.42	3E-02	0.24	5E-02	0.10	7E-02	0.20	2E-02
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Limonene	0.34	0.00	0.75	0.03	0.55	0.05	0.60	0.01	0.70	0.02
1,8-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p-Cymene	0.33	0.01	0.59	0.04	0.36	0.04	0.28	0.02	0.33	0.03
Norisoprenoids										
β-Damascenone	0.27	0.01	0.24	0.04	0.19	0.02	0.17	0.01	0.13	0.01
3-Hydroxy-β-damascone	2.61	0.05	2.48	0.04	2.66	0.32	2.58	0.05	1.69	0.09
3-Oxo-α-ionol	1.18	0.06	2.36	0.38	1.15	0.03	0.23	0.04	1.27	0.16
Vitispirane	0.02	0.00	0.02	0.00	0.04	0.01	0.02	0.00	0.58	0.19
TPB	0.33	0.05	0.50	0.03	0.98	0.12	0.38	0.04	25.04	7.22
TDN	0.77	0.24	2.34	0.26	4.97	0.59	1.95	0.04	59.20	18.45
Benzenoids and others										
Furfural	1.11	0.02	1.00	0.03	0.94	0.15	0.99	0.13	1.09	0.11
Benzaldehyde	32.45	6.52	21.44	3.14	18.63	1.95	15.89	0.83	15.09	0.28
Benzyl Alcohol	345.70	16.91	255.46	6.04	180.89	11.02	210.80	15.34	105.57	9.59
Vanillin	6.19	0.24	5.86	0.30	4.38	0.74	4.81	1.25	5.09	0.76
Methyl-vanillate	7.87	0.08	7.45	1.11	7.50	0.33	7.89	0.57	7.86	0.57
Ethyl-vanillate	149.79	1.18	131.90	3.49	142.92	19.88	197.30	2.98	145.03	6.51
Methyl-salycilate	0.21	0.02	0.27	0.09	0.26	0.04	1.68	0.13	0.35	0.03
2,6-Dimethoxy-Phenol	9.36	0.63	6.86	0.20	6.41	0.40	7.35	0.16	6.77	0.45
Eugenol	5.06	0.07	5.21	0.10	4.32	0.51	5.07	0.17	2.30	0.25
γ-Nonalactone	16.60	0.36	12.48	0.64	17.86	1.28	12.41	0.76	16.50	0.92

Appendix 1.3.2.9. Concentration (μg/L) and standard deviation (± μg/L) of volatile compounds of 2019 Corvina withered wines

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	97.56	6.06	148.43	8.49	155.49	4.90	117.62	3.72	210.88	33.25
Isoamyl alcool	146464.40	3861.20	247747.69	19137.00	156626.52	13461.65	149095.38	6278.39	128888.61	15654.02
1-Pentanol	75.65	5.51	63.16	10.84	65.83	4.03	52.32	3.23	103.36	4.86
Phenylethyl Alcohol	13514.08	2187.83	16952.62	1425.18	13928.96	1021.12	15093.30	744.44	8899.61	1888.63
Methionol	49.12	10.03	168.22	7.91	62.50	7.79	55.20	4.79	33.53	3.67
C_6 alcohols										
1-Hexanol	1420.57	111.24	1565.07	143.84	1499.73	59.88	1312.84	90.44	1666.84	230.85
trans-3-Hexen-1-ol	11.71	1.24	12.17	0.54	12.36	0.70	11.56	0.59	12.77	0.86
cis-3-Hexen-1-ol	169.65	18.90	192.21	11.23	107.64	4.97	101.50	9.29	114.32	17.91
cis-2-Hexen-1-ol	2.67	0.34	2.74	0.29	2.73	0.49	2.66	0.14	2.33	0.27
Acetate esters										
Isoamyl acetate	137.70	5.39	382.65	30.59	218.61	22.71	136.89	5.89	198.97	35.07
2-Phenethyl acetate	20.28	0.42	29.36	0.80	22.91	1.34	21.13	0.42	18.86	1.01
n-Hexyl acetate	1.82	0.14	4.94	0.86	2.62	0.53	1.98	0.43	1.84	0.10
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	6.85	0.26	4.27	0.05	7.19	0.22	5.89	0.68	5.46	0.11
Ethyl 3-methylbutanoate	7.89	0.12	4.29	0.62	8.16	0.10	6.34	0.42	5.64	0.28
Fatty acids ethyl esters										
Ethyl lactate	198.32	2.59	324.38	11.12	554.52	20.87	147.72	8.72	471.17	45.98
Ethyl butanoate	101.71	1.69	118.50	1.31	101.40	0.85	99.47	0.95	93.24	2.82
Ethyl 3-hydroxybutanoate	29.60	1.36	112.48	15.56	69.15	5.88	27.91	2.65	49.91	9.88
Ethyl hexanoate	164.89	9.57	338.20	3.44	233.61	26.66	207.71	9.21	165.71	30.57
Ethyl octanoate	51.20	5.29	137.44	8.35	77.48	9.54	100.98	6.81	43.15	9.18
Ethyl decanoate	8.76	0.79	15.97	1.65	10.49	1.07	23.58	4.43	10.60	2.49
Ethyl cinnamate	0.34	0.05	0.92	0.75	0.21	0.05	0.18	0.05	0.14	0.05
Fatty acids										
3-Methylbutanoic acid	420.74	52.19	326.18	24.57	273.13	23.27	245.32	5.63	269.69	37.72
Hexanoic acid	1631.04	47.48	2856.20	116.69	2399.54	203.78	2391.17	136.31	1384.53	203.95
Octanoic acid	834.29	42.29	1425.18	21.97	1146.15	101.12	1033.96	79.15	696.45	141.92
Terpenes										
trans-Linaloloxide	2.35	0.11	1.72	0.30	1.94	0.37	0.92	0.28	3.36	0.28
cis-Linaloloxide	3.19	0.24	2.02	0.12	3.27	0.19	1.62	0.31	5.34	0.32
Linalool	3.56	0.77	15.24	0.91	9.26	0.90	4.20	0.13	16.44	0.68
α-Terpineol	1.11	0.25	4.37	0.15	3.69	0.59	1.15	0.19	5.50	0.53
β-Citronellol	17.63	1.76	16.03	1.78	9.97	1.13	16.51	1.23	5.85	0.90
Geraniol	9.10	1.24	8.76	0.71	7.15	1.08	9.22	1.39	8.28	2.01
α-Phellandrene	1.64	0.03	0.71	0.05	0.65	0.05	0.46	0.07	0.72	0.02
α-Terpinen	0.74	0.04	0.25	0.01	0.34	0.06	0.16	0.04	0.27	0.01
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Limonene	0.36	0.03	1.23	0.22	1.31	0.16	0.36	0.06	1.63	0.09
1,8-Cineol	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00
p-Cymene	3.03	0.55	0.40	0.01	0.54	0.10	0.28	0.03	0.46	0.01
Norisoprenoids										
β-Damascenone	1.34	0.46	4.32	0.05	3.29	0.38	2.33	0.32	3.32	0.38
3-Hydroxy-β-damascone	0.35	0.03	0.32	0.07	0.36	0.03	0.40	0.03	0.40	0.07
3-Oxo-α-ionol	6.53	0.70	4.70	0.15	4.76	0.21	9.67	0.22	8.48	0.28
Vitispirane	0.38	0.04	1.52	0.08	4.70	0.67	0.75	0.07	4.45	0.57
TPB	0.00	0.00	0.04	0.01	0.07	0.01	0.03	0.01	0.06	0.01
TDN	0.09	0.01	0.70	0.07	0.99	0.16	0.38	0.03	0.86	0.10
Benzenoids and others										
Furfural	0.00	0.00	1.07	0.69	1.12	0.04	1.45	0.18	0.96	0.08
Benzaldehyde	24.87	5.11	4.32	0.80	5.37	0.33	20.81	3.33	48.02	13.03
Benzyl Alcohol	262.42	3.79	246.50	12.32	162.42	10.65	332.30	19.02	222.33	57.83
Vanillin	5.05	0.12	14.96	1.40	14.45	1.03	4.26	0.16	13.68	2.29
Methyl-vanillate	11.90	1.08	9.59	0.74	10.93	0.79	9.00	0.40	15.79	2.68
Ethyl-vanillate	588.00	45.02	113.76	4.84	145.94	4.67	189.69	10.73	271.00	0.95
Methyl-salycilate	0.25	0.03	0.00	0.00	0.00	0.00	0.40	0.69	0.18	0.31
2,6-Dimethoxy-Phenol	10.03	0.74	9.73	0.50	10.65	0.86	10.68	0.75	10.06	1.15
Eugenol	5.38	0.66	11.04	1.56	4.19	0.58	9.72	0.54	5.76	0.12
γ-Nonalactone	12.44	1.84	12.02	2.30	10.63	1.71	8.32	2.07	12.96	0.43

Appendix 1.3.2.10. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2017 Corvinone withered wines										
	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	79.28	0.65	203.56	30.18	218.36	2.87	126.41	3.11	122.28	6.61
Isoamyl alcool	216262.21	15910.17	241045.36	7075.16	228627.32	9647.11	219888.70	9540.09	220143.35	3657.41
1-Pentanol	70.94	3.49	108.51	1.14	109.69	7.46	61.88	2.17	106.91	8.06
Phenylethyl Alcohol	19891.93	513.92	19633.39	57.45	19316.12	1772.55	24419.09	918.95	17834.93	1555.04
Methionol	263.15	35.71	432.10	10.42	407.84	50.56	187.99	27.76	166.15	23.74
C_6 alcohols										
1-Hexanol	2121.25	178.22	2203.66	52.87	2367.25	180.51	2612.31	83.40	2978.93	345.56
trans-3-Hexen-1-ol	17.94	0.32	18.14	0.44	22.56	1.17	23.15	2.41	32.47	0.45
cis-3-Hexen-1-ol	52.25	4.54	43.01	1.07	33.31	3.14	34.32	1.23	44.21	6.79
cis-2-Hexen-1-ol	6.68	0.31	4.84	0.22	7.02	1.47	6.58	0.25	10.83	1.31
Acetate esters										
Isoamyl acetate	185.825	1.195	305.45	50.56	137.69	10.1	286.805	36.165	302.23	32.3
2-Phenethyl acetate	28.145	0.035	23.9	0.83	21.175	1.115	30.9	1.46	21.71	0.3
n-Hexyl acetate	10.45	0.13	14.265	0.025	13.255	0.235	14.91	0.24	15.58	0.65
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	7.38	0.1	5.75	0.54	5.48	0.02	7.075	0.045	6.15	0.57
Ethyl 3-methylbutanoate	6.83	0.13	6.5	1.1	4.78	0.36	6.73	0.19	8.215	0.715
Fatty acids ethyl esters										
Ethyl lactate	765.32	95.38	580.11	30.09	425.18	31.24	316.995	21.535	754.18	37.13
Ethyl butanoate	112.195	5.985	188.45	13.05	129.915	10.195	124.73	4.72	202.135	18.215
Ethyl 3-hydroxybutanoate	116.87	16.07	160.29	6.58	159.445	18.465	60.02	4.37	178.075	24.985
Ethyl hexanoate	255.07	9.84	392.325	28.135	285.085	23.705	325.425	14.255	421.395	34.475
Ethyl octanoate	124.395	7.465	216.45	6.9	141.525	17.985	145.98	15.61	216.72	22.36
Ethyl decanoate	29.80	1.43	56.52	3.98	40.33	4.57	37.59	1.38	47.59	3.29
Ethyl cinnamate	0.40	0.04	0.68	0.03	0.65	0.03	0.37	0.07	0.26	0.04
Fatty acids										
3-Methylbutanoic acid	369.84	24.47	359.18	29.50	447.30	9.38	409.73	2.72	320.71	21.85
Hexanoic acid	1625.77	72.72	2210.42	179.38	1891.89	179.08	1887.73	35.94	2315.20	187.07
Octanoic acid	1156.95	35.23	1606.59	61.24	1253.44	147.78	1181.02	46.60	1627.22	125.83
Terpenes										
trans-Linaloloxide	1.12	0.23	0.54	0.14	2.43	0.37	0.84	0.09	1.41	0.27
cis-Linaloloxide	1.23	0.08	0.65	0.04	1.76	0.21	0.16	0.02	0.99	0.02
Linalool	17.08	0.78	9.13	0.57	8.38	1.04	8.48	0.74	22.56	0.61
α-Terpineol	5.60	0.59	2.54	0.36	2.03	0.08	2.48	0.22	7.41	0.36
β-Citronellol	8.43	1.14	9.56	1.30	13.19	1.03	8.06	1.51	5.59	0.26
Geraniol	10.91	1.01	14.24	0.69	11.97	1.87	8.46	0.82	9.89	0.97
α-Phellandrene	0.73	0.73	0.65	0.65	0.62	0.62	0.72	0.72	0.52	0.52
α-Terpinen	0.07	0.01	0.07	0.01	0.06	0.00	0.05	0.02	0.10	0.01
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Limonene	0.38	0.38	0.31	0.31	0.26	0.26	0.35	0.35	0.38	0.38
1,8-Cineol	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
p-Cymene	0.16	0.02	0.15	0.04	0.14	0.03	0.14	0.06	0.20	0.01
Norisoprenoids										
β-Damascenone	4.53	0.62	8.30	0.29	9.89	0.93	4.33	0.22	6.06	0.04
3-Hydroxy-β-damascone	0.13	0.03	0.10	0.00	0.15	0.02	0.14	0.00	0.21	0.02
3-Oxo-α-ionol	2.66	0.21	3.03	0.14	3.61	0.39	2.85	0.18	2.26	0.15
Vitispirane	10.01	1.16	17.24	0.62	9.56	0.37	21.65	1.76	25.76	3.46
TPB	0.05	0.01	0.11	0.00	0.09	0.01	0.09	0.01	0.12	0.01
TDN	4.39	0.65	9.01	0.14	5.14	0.6	8.59	1.66	18.27	1.45
Benzenoids and others										
Furfural	3.35	0.16	2.57	0.02	2.98	0.02	1.87	0.04	2.32	0.17
Benzaldehyde	15.35	0.07	15.03	0.15	15.35	0.01	14.93	0.11	14.78	0.01
Benzyl Alcohol	8.29	8.29	17.50	0.63	14.99	14.99	22.16	1.65	9.06	0.45
Vanillin	5.37	0.10	5.58	0.37	6.08	0.79	6.13	0.64	8.60	0.16
Methyl-vanillate	11.88	0.22	10.65	0.64	10.51	0.50	12.49	0.25	22.29	0.05
Ethyl-vanillate	63.62	4.87	130.03	8.68	157.07	19.63	122.04	0.70	129.53	10.26
Methyl-salycilate	0.40	0.01	0.47	0.06	0.54	0.10	0.63	0.11	0.33	0.02
2,6-Dimethoxy-Phenol	4.62	0.54	6.53	0.02	6.33	0.51	5.72	1.38	5.55	0.10
Eugenol	0.90	0.02	1.33	0.01	1.24	0.08	0.97	0.22	1.02	0.15
γ-Nonalactone	18.34	0.97	17.21	0.21	44.18	1.30	6.58	0.01	12.57	0.27

Appendix 1.3.2.11. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2018 Corvinone withered wines										
	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	161.95	8.80	159.98	18.05	134.60	10.74	141.18	16.27	137.46	4.24
Isoamyl alcohol	232611.69	30378.17	209440.70	10670.12	175315.82	8762.72	234199.13	13677.19	185882.31	8588.92
1-Pentanol	96.27	7.57	101.67	11.21	113.80	1.82	74.71	4.64	92.73	2.08
Phenylethyl Alcohol	19733.16	3984.22	17328.79	482.01	13795.39	642.05	22308.34	1528.03	14830.17	864.67
Methionol	371.75	38.93	713.27	36.03	572.78	38.74	418.38	20.44	320.42	41.01
C_6 alcohols										
1-Hexanol	2590.09	110.65	2061.63	332.53	2970.21	56.18	2588.98	36.03	2881.74	207.42
trans-3-Hexen-1-ol	33.69	1.32	21.38	2.41	48.21	2.15	24.64	0.99	57.17	0.65
cis-3-Hexen-1-ol	50.61	3.57	40.42	2.81	30.70	0.44	40.73	0.42	39.15	1.99
cis-2-Hexen-1-ol	14.22	0.96	13.60	0.61	13.42	0.14	13.46	0.25	15.78	2.65
Acetate esters										
Isoamyl acetate	328.05	45.68	410.40	44.99	488.90	36.12	1000.38	117.45	523.87	23.49
2-Phenethyl acetate	1.59	0.16	3.45	0.51	7.60	0.43	16.13	1.58	9.09	0.29
n-Hexyl acetate	23.02	2.06	24.19	0.57	22.60	0.92	39.95	3.17	28.26	2.31
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	4.12	0.16	3.24	0.07	2.39	0.04	3.25	0.22	3.62	0.18
Ethyl 3-methylbutanoate	3.81	0.43	3.14	0.37	2.57	0.20	2.42	0.36	3.93	0.27
Fatty acids ethyl esters										
Ethyl lactate	257.11	21.54	828.09	90.48	210.33	14.72	143.89	13.16	407.64	47.51
Ethyl butanoate	171.58	12.17	141.79	10.69	191.09	13.14	188.79	8.92	177.58	6.73
Ethyl 3-hydroxybutanoate	164.57	13.33	132.38	3.65	133.59	7.11	124.24	12.71	170.86	9.54
Ethyl hexanoate	357.64	13.56	276.81	29.84	361.10	39.09	391.94	60.83	427.51	34.36
Ethyl octanoate	142.65	18.02	113.45	22.48	132.22	18.56	162.05	40.32	185.56	24.18
Ethyl decanoate	27.60	3.67	22.69	4.50	25.69	1.21	48.65	8.93	40.32	8.90
Ethyl cinnamate	0.06	0.01	0.10	0.09	0.29	0.05	0.03	0.01	0.17	0.01
Fatty acids										
3-Methylbutanoic acid	513.52	15.60	391.65	28.06	381.43	10.06	420.87	8.36	385.68	42.81
Hexanoic acid	2887.63	205.69	1680.13	97.26	3455.42	216.94	2107.72	94.36	2158.57	165.28
Octanoic acid	3433.86	50.69	3385.16	106.95	3454.22	229.50	3799.37	291.56	3798.71	138.50
Terpenes										
trans-Linaloloxide	0	0	0	0	0	0	0	0	0	0
cis-Linaloloxide	0	0	0	0	0	0	0	0	0	0
Linalool	8.81	0.42	8.06	1.32	5.63	0.29	5.83	0.45	13.55	2.11
α-Terpineol	1.51	0.16	1.39	0.16	0.61	0.11	1.00	0.09	2.72	0.08
β-Citronellol	12.02	1.80	12.96	1.12	13.20	0.60	10.98	1.20	8.20	1.45
Geraniol	6.45	0.34	15.62	1.12	16.06	0.78	12.58	0.49	7.98	0.79
α-Phellandrene	2.78	0.11	2.15	0.20	2.47	0.25	2.83	0.14	3.17	0.27
α-Terpinen	0.10	6E-03	0.12	6E-03	0.14	6E-03	0.05	6E-03	0.14	2E-02
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Limonene	0.61	0.02	0.46	0.03	0.33	0.02	0.43	0.06	1.04	0.07
1,8-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p-Cymene	0.18	0.01	0.19	0.01	0.18	0.02	0.08	0.01	0.24	0.04
Norisoprenoids										
β-Damascenone	0.16	0.01	0.16	0.02	0.18	0.03	0.08	0.01	0.14	0.02
3-Hydroxy-β-damascone	1.91	0.06	1.42	0.09	3.14	0.12	1.58	0.14	1.76	0.08
3-Oxo-α-ionol	2.30	0.19	2.74	0.97	2.50	0.33	0.37	0.04	3.45	0.48
Vitispirane	0.02	0.00	0.01	0.01	0.02	0.00	0.07	0.02	0.34	0.10
TPB	0.43	0.04	0.40	0.02	0.37	0.02	2.21	0.65	20.60	6.16
TDN	2.29	0.07	2.60	0.10	2.57	0.17	20.27	2.62	72.57	17.01
Benzenoids and others										
Furfural	1.11	0.07	1.02	0.13	1.06	0.09	1.27	0.20	1.27	0.12
Benzaldehyde	17.78	0.61	15.21	0.22	18.17	1.03	14.18	0.32	14.32	0.11
Benzyl Alcohol	53.47	4.44	78.66	20.57	36.10	0.28	21.67	2.34	18.52	2.68
Vanillin	7.93	0.03	4.76	0.25	4.61	0.42	6.33	0.57	4.47	0.76
Methyl-vanillate	25.95	2.54	9.83	0.22	12.85	0.96	13.00	1.11	18.89	0.40
Ethyl-vanillate	211.81	2.84	139.22	4.84	214.13	6.29	209.28	10.35	224.09	4.44
Methyl-salycilate	0.28	0.03	0.37	0.05	0.35	0.04	0.25	0.05	0.47	0.09
2,6-Dimethoxy-Phenol	8.04	0.43	6.51	0.17	7.70	0.40	7.42	0.15	7.50	0.39
Eugenol	1.45	0.15	2.16	0.19	1.88	0.03	1.16	0.01	0.83	0.10
γ-Nonalactone	15.70	0.54	12.06	1.82	29.14	2.62	11.80	0.26	16.70	0.27

Appendix 1.3.2.12. Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of 2019 Corvinone withered wines										
	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	160.52	3.58	128.35	12.85	113.53	8.57	103.32	16.80	145.36	2.47
Isoamyl alcohol	223055.76	15410.14	244949.17	43806.63	219340.11	10866.19	193208.67	15391.15	136008.64	9285.27
1-Pentanol	95.72	16.67	95.42	14.67	114.79	16.22	58.89	7.28	107.56	8.30
Phenylethyl Alcohol	13658.31	3015.11	17544.39	1806.04	12769.09	2304.24	16772.54	1469.23	9103.25	404.45
Methionol	68.46	2.80	329.27	58.90	277.04	58.85	221.68	26.56	64.34	6.87
C_6 alcohols										
1-Hexanol	1897.42	102.09	2720.05	373.97	2249.95	276.33	1744.53	147.05	2282.79	244.89
trans-3-Hexen-1-ol	16.22	0.53	29.07	6.12	23.74	0.73	19.51	2.14	21.78	0.24
cis-3-Hexen-1-ol	35.40	7.37	40.49	6.51	33.51	4.29	30.72	2.68	31.20	3.66
cis-2-Hexen-1-ol	3.37	0.41	7.14	0.70	6.40	0.31	4.92	0.40	5.88	0.94
Acetate esters										
Isoamyl acetate	334.27	17.68	271.26	21.61	190.71	11.54	481.06	44.12	213.71	10.54
2-Phenethyl acetate	29.44	4.47	26.73	3.24	19.33	0.68	36.41	3.23	19.20	0.90
n-Hexyl acetate	4.98	0.41	4.55	0.98	1.72	0.34	7.69	1.18	4.03	0.79
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	6.25	0.57	4.97	0.38	4.54	0.10	5.27	0.24	4.61	0.33
Ethyl 3-methylbutanoate	5.69	0.13	5.02	0.71	3.72	0.24	4.91	0.08	5.36	0.53
Fatty acids ethyl esters										
Ethyl lactate	235.71	10.40	243.74	41.85	246.71	2.32	104.46	11.06	289.22	8.16
Ethyl butanoate	114.24	9.29	122.74	2.38	135.77	4.87	142.54	13.39	118.26	2.79
Ethyl 3-hydroxybutanoate	65.15	11.80	120.99	6.78	120.13	21.89	73.08	8.30	31.78	6.31
Ethyl hexanoate	348.53	6.03	401.27	74.81	351.90	12.41	381.78	21.47	232.67	7.91
Ethyl octanoate	73.70	6.16	118.35	1.54	112.73	4.14	121.82	20.80	66.73	2.62
Ethyl decanoate	13.88	3.29	18.97	3.53	17.51	3.17	16.64	1.47	13.45	0.72
Ethyl cinnamate	0.36	0.01	0.49	0.12	0.33	0.05	0.24	0.03	0.62	0.74
Fatty acids										
3-Methylbutanoic acid	313.74	68.00	468.16	82.07	417.02	27.82	375.61	41.05	342.97	22.32
Hexanoic acid	3898.54	132.30	3102.39	144.63	2808.27	385.07	3332.24	176.24	2050.66	55.10
Octanoic acid	1485.69	424.88	1934.73	345.84	1189.50	258.09	1333.16	206.63	1096.02	72.00
Terpenes										
trans-Linaloloxide	1.13	0.04	1.43	0.04	0.95	0.09	0.75	0.05	1.07	0.08
cis-Linaloloxide	1.72	0.44	0.28	0.48	0.86	0.22	0.00	0.00	1.53	0.22
Linalool	9.02	0.61	13.04	1.26	14.14	2.49	9.72	0.29	14.02	1.87
α-Terpineol	3.52	0.46	3.88	0.30	4.23	0.28	2.96	0.09	6.21	0.97
β-Citronellol	9.43	1.28	11.70	1.46	12.54	0.22	12.80	0.96	10.82	2.17
Geraniol	4.92	1.37	12.66	1.82	8.27	1.52	8.60	0.61	7.36	0.93
α-Phellandrene	0.47	0.06	0.60	0.06	0.55	0.03	0.82	0.04	0.66	0.10
α-Terpinen	0.30	0.04	0.24	0.02	0.28	0.03	0.54	0.04	0.26	0.04
1,4-Cineol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Limonene	0.80	0.05	1.15	0.10	1.02	0.16	0.90	0.09	1.83	0.12
1,8-Cineol	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
p-Cymene	0.56	0.07	0.29	0.05	0.36	0.05	0.56	0.10	0.39	0.07
Norisoprenoids										
β-Damascenone	3.32	0.25	6.89	0.52	7.93	1.40	5.90	0.33	6.60	1.23
3-Hydroxy-β-damascone	0.17	0.07	0.12	0.02	0.24	0.03	0.23	0.01	0.32	0.04
3-Oxo-α-ionol	4.49	1.98	3.41	0.27	6.23	1.49	6.95	0.71	7.65	0.49
Vitispirane	8.38	0.41	7.56	1.18	6.65	0.92	5.08	0.44	18.17	0.83
TPB	0.03	0.00	0.05	0.01	0.05	0.01	0.04	0.01	0.08	0.01
TDN	0.65	0.03	0.81	0.10	0.80	0.11	0.50	0.09	1.80	0.15
Benzenoids and others										
Furfural	0.34	0.58	1.33	0.11	1.54	0.13	1.39	0.10	1.00	0.06
Benzaldehyde	6.82	1.23	3.97	0.58	7.75	1.58	3.92	0.38	4.84	0.72
Benzyl Alcohol	52.56	4.44	43.82	0.62	52.65	8.70	56.41	11.10	65.07	9.93
Vanillin	10.21	1.65	9.34	0.70	8.87	1.73	5.71	0.85	8.25	1.06
Methyl-vanillate	21.40	8.62	16.74	1.80	22.83	0.63	14.86	0.41	28.24	1.48
Ethyl-vanillate	346.50	154.16	105.58	20.95	180.08	26.32	77.60	6.55	250.60	9.40
Methyl-salycilate	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.04	1.41	0.07
2,6-Dimethoxy-Phenol	11.42	1.62	8.57	0.77	9.83	1.76	10.17	0.76	10.95	0.17
Eugenol	2.03	0.47	1.16	0.06	1.78	0.37	2.92	0.46	1.66	0.12
γ-Nonalactone	13.47	2.71	13.20	1.16	28.29	0.32	8.81	0.48	12.56	0.38

Appendix 1.3.2.13. Significant different compounds in Corvina withered wines according to Kruskal Wallis (α=0.05) multiple pairwise comparisons Steel-Dwass-Critchlow-Fligner

	Vineyard 1	Vineyard 2	Vineyard 3	Vineyard 4	Vineyard 5	Pr > F
Linalool	a	b	a	a	c	**<0.0001**
Ethyl-3-methylbutanoate	c	a	c	b	b	**<0.0001**
α-Terpineol	a	c	bc	ab	d	**<0.0001**
β-Citronellol	d	cd	ab	bc	a	**<0.0001**
β-Damascenone	a	c	b	a	b	**<0.0001**
Ethyl lactate	a	b	b	a	b	**<0.0001**
TPB	a	a	a	a	b	**<0.0001**
TDN	a	a	a	a	b	**<0.0001**
Vanillin	c	a	ab	a	b	**<0.0001**
Ethyl-vanillate	c	a	ab	bc	bc	**0.000**
Ethyl-2-methylbutanoate	bc	a	c	bc	b	**0.000**
cis-3-Hexen-1-ol	bc	c	ab	a	a	**0.000**
γ-Nonalactone	b	b	b	a	b	**0.000**
1-Butanol	a	c	bc	ab	bc	**0.000**
trans-Linaloloxide	b	b	b	a	b	**0.001**
cis-Linaloloxide	bc	ab	abc	a	c	**0.001**
Ethyl 3-hydroxybutanoate	ab	c	bc	a	abc	**0.001**
n-Hexyl acetate	a	b	b	ab	a	**0.002**
Eugenol	a	b	a	a	a	**0.002**
1-Pentanol	ab	b	ab	a	b	**0.002**
2-Phenethyl acetate	a	ab	ab	b	a	**0.003**
Methyl-vanillate	a	a	ab	ab	b	**0.003**
Isoamyl acetate	a	b	b	ab	ab	**0.004**
Limonene	a	b	ab	ab	b	**0.005**
Vitispirane	ab	a	ab	ab	b	**0.006**
3-Methylbutanoic acid	b	a	ab	ab	a	**0.007**
Terpinolene	a	b	b	ab	b	**0.011**
Benzaldehyde	b	ab	a	ab	ab	**0.017**
Methionol	a	b	ab	ab	ab	**0.017**
Geraniol	ab	b	a	ab	a	**0.020**
p-Cymene	b	a	a	a	ab	**0.022**
Ethyl cinnamate	a	ab	a	a	b	**0.027**
Benzyl alcohol	b	ab	ab	ab	a	**0.050**

Appendix 1.3.2.14. Significant different compounds in Corvinone withered wines according to Kruskal Wallis (α=0.05) multiple pairwise comparisons Steel-Dwass-Critchlow-Fligner

	Vineyard 1	Vineyard 2	Vineyard 3	Vineyard 4	Vineyard 5	Pr > F
Linalool	a	a	a	a	b	<0.0001
TDN	a	a	a	a	b	<0.0001
1-Pentanol	b	c	d	a	cd	<0.0001
Ethyl-2-methylbutanoate	d	bc	a	c	ab	<0.0001
2-Phenethyl acetate	c	bc	a	d	ab	<0.0001
α-Terpineol	b	ab	a	a	c	<0.0001
Vitispirane	ab	ab	a	b	c	<0.0001
γ-Nonalactone	b	ab	c	a	b	<0.0001
Methyl-vanillate	b	a	ab	a	c	<0.0001
TPB	a	a	a	a	b	<0.0001
Geraniol	a	c	bc	ab	a	<0.0001
Ethyl-3-methylbutanoate	c	b	a	b	bc	<0.0001
Ethyl lactate	b	b	b	a	b	<0.0001
Phenylethyl alcohol	ab	bc	a	c	a	<0.0001
1,8-Cineole	bc	a	a	ab	c	<0.0001
β-Damascenone	a	b	b	a	b	<0.0001
Isoamyl acetate	a	a	a	b	a	<0.0001
cis-3-Hexen-1-ol	c	bc	ab	a	ab	<0.0001
Limonene	a	a	a	a	b	<0.0001
trans-3-Hexen-1-ol	a	ab	b	a	b	<0.0001
β-Citronellol	ab	bc	c	bc	a	0,000
3-Hydroxy-β-damascone	a	a	a	a	b	0,000
Vanillin	ab	a	ab	a	b	0,001
cis-2-Hexen-1-ol	a	b	ab	ab	b	0,001
trans-Linaloloxide	b	b	b	a	b	0,001
Terpinolene	a	a	a	a	b	0,001
1,4-Cineole	a	a	a	a	b	0,001
1-Hexanol	ab	ab	b	a	b	0,004
cis-Linaloloxide	ab	a	b	ab	ab	0,005
p-Cymene	b	a	ab	ab	b	0,007
Benzaldehyde	b	ab	b	a	ab	0,012
3-Methylbutanoic acid	ab	ab	ab	b	a	0,012
Ethyl-vanillate	ab	a	ab	a	b	0,012
Ethyl decanoate	a	b	ab	ab	ab	0,034
1-Butanol	a	a	a	a	a	0,042
Furfural	b	b	a	b	b	0,050

Appendix 2.3.1.1 Correlation matrix and correlation coefficients of terpenes and norisoprenoids with glucose + fructose content

	Corvina		**Corvinone**	
	Correlation matrix	**R^2**	**Correlation matrix**	**R^2**
Total norisoprenoids	0.071	0.005	0.214	0.046
β-Damascenone	-0.104	0.011	0.149	0.022
Vitispirane	0.079	0.006	0.230	0.053
TPB	0.045	0.002	0.211	0.044
TDN	0.151	0.023	0.156	0.024
3-Hydroxy-β-damascone	-0.270	0.073	-0.100	0.010
Total terpenes	0.090	0.008	**0.335**	**0.112**
trans-Linaloloxide	0.149	0.022	0.118	0.014
cis-Linaloloxide	-0.036	0.001	0.050	0.003
Linalool	0.154	0.024	0.203	0.041
α-Terpineol	0.103	0.011	0.284	0.081
β-Citronellol	**-0.340**	**0.116**	-0.164	0.027
Geraniol	0.037	0.001	**0.378**	**0.143**
α-Phellandrene	-0.033	0.001	**0.467**	**0.218**
1,4-Cineol	0.208	0.043	0.166	0.028
Limonene	-0.021	0.000	0.203	0.041
1,8-Cineol	0.095	0.009	0.260	0.068
p-Cymene	-0.066	0.004\	**0.529**	**0.280**
Nerol	0.044	0.002	0.081	0.007

Bold values show significant correlation (pearson. α=0.05) with glucose + fructose content

Appendix 2.3.1.2. Correlation coefficient (R^2) between fresh grapes wine free terpenes and grape free and/or bound terpenes

Wine free terpenes→	trans-Linaloloxide	cis-Linaloloxide	Linalool	α-Terpineol	β-Citronellol	Geraniol	α-Phellandrene	1,4-Cineol	Limonene	1,8-Cineol	p-Cymene	Nerol
Corvina												
Grape free terpenes												
α-Phellandrene	0.053	**0.342**	0.110	0.197	0.131	**0.407**	0.131	0.009	0.051	0.161	0.013	0.005
Limonene	0.050	0.000	0.103	0.045	0.090	0.195	0.022	0.203	0.018	0.036	0.051	0.061
p-Cymene	0.008	0.094	0.065	0.127	0.047	0.259	0.055	0.002	**0.495**	**0.384**	**0.760**	**0.304**
Terpinolene	<0.0001	**0.529**	0.205	**0.408**	0.218	0.004	0.000	0.000	**0.753**	**0.764**	**0.508**	**0.282**
cis-Linaloloxide	**0.338**	**0.680**	**0.466**	**0.574**	**0.317**	0.190	0.259	0.215	0.014	**0.415**	0.000	0.086
trans-Linaloloxide	**0.350**	**0.699**	**0.567**	**0.663**	**0.381**	0.145	0.217	**0.309**	0.037	**0.482**	0.004	0.080
Linalool	**0.472**	**0.686**	**0.928**	**0.949**	**0.638**	0.077	0.134	**0.493**	0.033	**0.582**	0.033	0.006
α-Terpineol	0.002	**0.467**	0.201	**0.394**	0.213	0.011	0.007	<0.0001	**0.754**	**0.777**	**0.634**	**0.267**
β-Citronellol	0.242	0.159	**0.475**	**0.357**	**0.360**	0.129	**0.279**	**0.488**	0.050	0.077	0.025	0.032
Nerol	0.046	0.137	0.093	0.128	0.035	**0.545**	**0.539**	0.079	0.000	0.234	0.000	0.051
Geraniol	0.079	0.160	0.209	0.230	**0.453**	**0.313**	0.001	0.100	0.080	0.212	0.142	0.204
Grape bound terpenes												
Limonene	**0.357**	0.029	0.069	0.032	0.039	0.005	0.000	0.178	0.213	0.026	0.059	**0.340**
p-Cymene	**0.444**	**0.311**	**0.678**	**0.546**	**0.422**	0.224	**0.280**	**0.509**	0.091	0.141	0.074	0.030
Terpinolene												
trans-Linaloloxide	0.176	**0.513**	**0.433**	**0.540**	**0.279**	0.064	0.112	0.185	0.160	**0.465**	0.079	0.118
cis-Linaloloxide	0.209	**0.609**	**0.383**	**0.570**	**0.282**	0.051	0.091	0.112	0.254	**0.596**	0.144	0.151
Linalool	0.035	0.211	0.132	0.222	0.155	0.052	0.073	<0.0001	**0.688**	**0.446**	**0.555**	0.166
α-Terpineol	0.010	**0.268**	0.138	0.240	0.221	0.135	0.024	0.012	**0.630**	**0.536**	**0.653**	0.215
β-Citronellol	0.037	0.039	0.100	0.091	0.202	0.241	0.072	0.026	0.022	0.074	0.099	0.004
Nerol	0.018	0.102	0.112	0.151	0.110	0.113	0.002	0.087	0.124	0.167	0.173	0.068
Geraniol	0.118	0.131	**0.292**	0.235	**0.366**	0.122	0.141	0.156	0.014	0.071	0.038	0.006
Grape bound + free terpenes												
Linalool	0.012	**0.441**	**0.520**	**0.529**	**0.362**	0.005	0.005	0.068	**0.503**	**0.642**	**0.415**	0.119
geraniol	0.158	0.219	**0.401**	**0.360**	**0.615**	<0.0001	0.091	0.206	0.002	0.178	0.001	0.024
α-Terpineol	0.000	**0.443**	0.195	**0.377**	0.222	0.024	0.009	0.000	**0.757**	**0.757**	**0.660**	**0.266**
Corvinone												
Grape free terpenes												
alpha-phellandrene	0.060	0.241	0.002	0.007	0.209	**0.554**	0.105	0.055	0.013	0.004	0.000	0.040
Limonene	0.029	0.002	0.186	**0.296**	0.001	0.058	0.001	0.012	**0.404**	**0.270**	**0.459**	0.200
p-Cymene	0.009	0.006	0.036	0.066	0.001	0.036	0.090	0.002	0.262	0.002	**0.448**	0.076
Terpinolene	**0.292**	**0.320**	0.247	**0.346**	**0.314**	0.028	0.185	0.026	**0.683**	0.048	**0.570**	0.127
cis-Linaloloxide	0.164	0.067	**0.358**	**0.352**	0.244	0.218	0.071	**0.493**	0.053	0.004	0.002	0.087
trans-Linaloloxide	0.131	0.042	0.264	**0.277**	0.141	0.217	0.043	**0.322**	0.036	0.001	0.001	0.016
Linalool	0.018	0.181	**0.703**	**0.804**	**0.279**	0.046	0.088	0.160	0.078	0.112	0.190	<0.0001
α-Terpineol	**0.267**	0.205	0.197	**0.286**	0.187	0.001	0.059	0.027	**0.725**	0.023	**0.719**	0.208
β-Citronellol												
Nerol	0.149	0.037	0.113	0.163	0.026	0.048	0.120	0.013	**0.450**	0.048	0.235	**0.595**
Geraniol	0.128	0.063	0.054	0.096	0.147	0.019	**0.469**	0.036	0.090	0.003	0.001	0.169
Grape bound terpenes												
Limonene	0.163	0.005	0.006	0.004	0.001	<0.0001	0.009	0.209	**0.317**	0.104	0.172	**0.360**
p-Cymene	**0.371**	**0.267**	0.212	0.177	**0.279**	0.176	0.107	**0.472**	0.148	0.004	0.029	0.190
Terpinolene	0.030	0.133	0.058	0.068	0.179	0.085	0.034	0.028	0.049	0.060	0.057	0.004
trans-Linaloloxide	0.126	**0.285**	0.164	0.211	0.209	0.046	0.263	0.016	0.162	0.001	0.094	0.062
cis-Linaloloxide	0.051	0.242	0.234	**0.284**	0.233	0.064	0.219	0.046	0.104	0.001	0.077	0.040
Linalool	0.230	0.027	0.197	**0.324**	0.015	0.002	0.022	0.073	**0.673**	0.220	**0.534**	0.230
α-Terpineol	0.143	0.038	0.179	0.221	0.019	0.004	0.006	0.063	**0.587**	0.157	**0.619**	0.093
β-Citronellol	0.117	0.097	0.004	<0.0001	<0.0001	0.011	0.155	0.028	0.003	0.007	0.081	0.064
Nerol	0.170	0.211	0.133	0.106	**0.368**	0.096	0.158	**0.471**	0.252	<0.0001	0.113	**0.534**
Geraniol	**0.331**	0.141	0.227	0.223	0.155	0.238	0.118	**0.398**	0.105	0.094	0.036	0.127
Grape bound + free terpenes												
Linalool	0.108	0.071	**0.559**	**0.542**	0.072	0.010	0.045	0.006	**0.532**	0.225	**0.506**	0.142
geraniol	**0.306**	0.146	0.231	0.231	0.165	0.238	0.137	**0.399**	0.094	0.094	0.035	0.112
α-Terpineol	0.263	0.188	0.204	**0.292**	0.167	0.001	0.045	0.032	**0.744**	0.033	**0.742**	0.202

Bold values show significant correlation (pearson, α=0.05)

Appendix 2.3.1.3. Correlation coefficient (R^2) between withered grapes wines free terpenes and grape free and/or bound terpenes

	trans-Linaloloxide	cis-Linaloloxide	Linalool	α-Terpineol	β-citronellol	Geraniol	α-Phellandrene	α-terpinen	1,4-Cineole	Limonene	1,8-Cineole	p-Cymene	Terpinolene
Corvina													
Grape free terpenes													
A-Pphellandrene	0.111	0.094	**0.415**	**0.390**	0.078	0.002	0.006	0.045	0.034	0.193	0.016	0.022	0.009
Limonene	**0.465**	**0.288**	**0.350**	**0.548**	0.181	0.025	0.172	0.001	0.193	0.102	0.258	<0.0001	0.001
p-Cymene	0.128	0.084	0.104	0.055	0.080	0.007	0.006	**0.772**	0.001	0.062	0.016	**0.941**	0.055
Terpinolene	**0.606**	**0.514**	**0.369**	**0.616**	0.133	0.035	**0.373**	0.001	0.041	**0.293**	0.174	<0.0001	0.120
trans-Linaloloxide	**0.383**	**0.327**	0.035	0.116	0.065	0.009	**0.566**	0.010	0.110	0.005	0.171	0.024	0.199
cis-Linaloloxide	**0.382**	**0.477**	<0.0001	0.016	0.204	0.034	0.158	0.014	0.038	0.256	0.001	0.010	0.134
Linalool	0.256	**0.322**	**0.270**	**0.322**	0.252	0.029	0.075	0.007	0.037	**0.718**	0.002	0.062	0.029
α-Terpineol	**0.481**	**0.518**	**0.306**	**0.419**	0.257	0.075	0.258	0.003	0.000	**0.572**	0.015	0.018	0.120
β-Citronellol	0.024	0.036	0.165	0.168	**0.551**	0.005	0.001	0.186	0.057	0.028	0.207	0.093	0.093
Nerol	**0.273**	0.108	0.028	0.079	0.007	0.004	0.066	0.001	**0.374**	0.007	0.117	<0.0001	0.001
Geraniol	**0.506**	**0.489**	0.011	0.019	0.007	0.117	0.199	0.185	0.014	0.217	0.005	0.159	**0.427**
Grape bound terpenes													
Limonene	0.011	0.025	**0.303**	0.221	0.126	0.018	0.189	**0.410**	**0.359**	<0.0001	**0.427**	**0.459**	0.081
p-Cymene	**0.446**	**0.440**	0.023	0.006	0.006	0.057	0.039	**0.332**	0.094	0.075	0.035	**0.428**	**0.323**
Terpinolene													
trans-Linaloloxide	**0.379**	**0.375**	0.018	0.074	0.003	0.000	0.005	**0.480**	0.023	0.047	<0.0001	**0.617**	0.087
cis-Linaloloxide	**0.428**	**0.301**	0.185	**0.336**	0.001	0.010	0.040	0.199	0.011	0.026	0.122	**0.313**	0.016
Linalool	0.034	0.022	**0.523**	**0.524**	0.049	0.099	0.000	0.021	0.004	0.116	0.080	0.019	0.062
α-Terpineol	0.010	0.009	**0.444**	**0.378**	0.088	0.066	0.017	0.011	0.001	0.175	0.032	0.020	0.064
β-Citronellol	**0.447**	**0.374**	0.030	0.001	0.123	0.033	0.018	**0.540**	0.063	0.064	0.080	**0.516**	0.187
Nerol	0.183	0.195	0.036	0.007	0.055	0.032	0.014	0.090	0.194	<0.0001	0.010	0.120	0.145
Geraniol	0.153	0.205	0.040	0.096	0.007	0.026	0.137	0.024	0.220	0.035	0.077	0.017	0.103
Grape bound + free terpenes													
Linalool	0.174	0.195	**0.458**	**0.490**	0.187	0.001	0.031	0.014	0.024	**0.509**	0.009	0.052	<0.0001
geraniol	0.096	0.063	0.060	0.014	0.018	0.173	0.010	0.239	0.215	0.065	0.076	0.197	0.099
α-Terpineol	**0.376**	**0.402**	**0.404**	**0.493**	0.254	0.028	0.158	0.006	0.000	**0.556**	0.022	0.022	0.053
Corvinone													
Grape free terpenes													
α Phellandrene	0.021	0.041	**0.696**	**0.546**	**0.313**	0.149	0.005	0.017	0.250	0.067	0.160	0.022	0.067
Limonene	0.119	0.256	0.047	0.157	0.104	**0.290**	0.228	0.138	0.001	0.092	<0.0001	**0.413**	0.171
p-Cymene	0.025	0.211	0.010	0.006	0.029	0.207	0.066	0.077	0.014	0.006	0.014	**0.326**	0.087
Terpinolene	**0.341**	0.174	**0.665**	**0.788**	0.127	0.036	**0.484**	0.044	**0.278**	0.138	0.226	0.040	0.193
trans-Linaloloxide	**0.477**	**0.315**	0.192	**0.355**	0.042	0.062	**0.776**	0.073	0.119	0.031	0.194	0.134	0.238
cis-Linaloloxide	0.106	**0.301**	0.131	0.073	0.112	0.001	<0.0001	0.005	0.105	0.018	0.003	0.002	0.002
Linalool	0.111	0.046	**0.553**	**0.569**	0.031	0.260	0.153	**0.351**	0.018	**0.414**	<0.0001	**0.322**	0.097
α-Terpineol	0.193	0.194	**0.426**	**0.601**	0.054	**0.334**	**0.290**	**0.454**	0.001	**0.520**	0.001	**0.563**	0.231
β-Citronellol	0.103	**0.315**	0.003	0.137	<0.0001	**0.324**	0.259	0.245	0.067	**0.454**	0.038	**0.499**	**0.303**
Nerol	0.077	0.161	0.002	0.027	0.001	0.241	0.218	**0.393**	0.063	0.095	0.069	**0.666**	**0.341**
Geraniol	0.113	0.242	0.006	0.123	0.001	**0.271**	0.254	**0.381**	0.087	**0.385**	0.087	**0.653**	**0.462**
Grape bound terpenes													
Limonene	0.087	0.063	0.128	0.064	0.233	0.001	0.022	**0.337**	**0.360**	0.175	**0.509**	**0.279**	0.144
p-Cymene	0.206	0.073	0.201	**0.355**	0.032	0.082	**0.492**	**0.333**	0.025	0.163	0.013	**0.305**	**0.526**
Terpinolene													
trans-Linaloloxide	0.025	0.198	0.000	0.014	<0.0001	0.238	0.099	0.134	0.047	0.033	0.056	**0.358**	0.164
cis-Linaloloxide	0.019	0.201	0.017	0.002	0.020	0.202	0.052	0.074	0.023	0.005	0.021	**0.318**	0.080
Linalool	0.127	0.124	**0.617**	**0.648**	0.115	**0.266**	0.138	0.096	0.099	0.166	0.070	0.102	0.019
α-Terpineol	0.150	**0.377**	**0.277**	**0.517**	0.147	**0.288**	**0.291**	0.232	0.007	**0.321**	0.009	**0.478**	0.140
β-Citronellol	0.194	**0.397**	0.041	0.213	0.001	0.038	0.157	0.007	0.012	0.213	0.006	0.022	**0.315**
Nerol	**0.310**	0.238	0.033	0.108	<0.0001	0.237	**0.424**	**0.397**	0.000	0.081	0.010	**0.510**	0.194
Geraniol	**0.270**	0.230	0.018	0.126	0.014	**0.302**	**0.421**	**0.401**	0.014	0.075	0.028	**0.522**	0.263
Grape bound + free terpenes													
Linalool	0.123	0.072	**0.649**	**0.637**	0.056	**0.277**	0.157	0.262	0.040	**0.337**	0.009	0.248	0.068
geraniol	0.173	0.075	0.012	0.045	0.026	0.115	0.219	0.145	0.103	0.003	0.146	0.137	0.039
α-Terpineol	0.194	0.233	**0.416**	**0.614**	0.070	**0.342**	**0.304**	**0.430**	0.002	**0.505**	<0.0001	**0.574**	0.224

Bold values show significant correlation (pearson, α=0.05)

Appendix 2.3.1.4. Correlation matrix and coefficients of esters with nitrogen and glucose + fructose content

	PAN	**Ammonia**	**YAN**	**Glucose + fructose**	**PAN**	**Ammonia**	**YAN**	**Glucose + fructose**
		Correlation matrix				**R^2**		
Corvina								
Acetate esters	**0.389**	0.302	**0.354**	0.093	**0.152**	0.091	**0.125**	0.009
Isoamyl acetate	**0.393**	**0.310**	**0.361**	0.081	**0.155**	**0.096**	**0.130**	0.007
2-Phenethyl acetate	0.049	-0.109	-0.036	**0.343**	0.002	0.012	0.001	**0.118**
n-Hexyl acetate	**0.669**	**0.539**	**0.620**	0.188	**0.448**	**0.290**	**0.384**	0.036
Ethyl esters	0.064	0.097	0.084	0.056	0.004	0.009	0.007	0.003
Ethyl lactate	**0.341**	**0.341**	**0.352**	0.017	**0.116**	**0.117**	**0.124**	0.000
Ethyl butanoate	0.186	0.165	0.180	0.142	0.034	0.027	0.032	0.020
Ethyl 3-hydroxybutanoate	0.219	**0.352**	0.299	-0.110	0.048	**0.124**	0.089	0.012
Ethyl hexanoate	0.048	0.065	0.059	0.065	0.002	0.004	0.003	0.004
Ethyl octanoate	-0.062	-0.067	-0.066	0.123	0.004	0.004	0.004	0.015
Ethyl decanoate	-0.142	-0.170	-0.162	0.125	0.020	0.029	0.026	0.016
Branched-chain fatty acid ethyl esters	-0.301	**-0.336**	**-0.330**	**0.479**	0.090	**0.113**	**0.109**	**0.230**
Ethyl-2-methylbutanoate	-0.300	**-0.323**	**-0.323**	**0.485**	0.090	**0.105**	**0.104**	**0.235**
Ethyl 3-methylbutanoate	-0.297	**-0.343**	**-0.332**	**0.468**	0.088	**0.118**	**0.110**	**0.219**
Corvinone								
Acetate esters	0.200	0.263	0.247	-0.116	0.040	0.069	0.061	0.013
Isoamyl acetate	0.224	0.280	0.269	-0.111	0.050	0.078	0.072	0.012
2-Phenethyl acetate	**-0.435**	-0.287	**-0.384**	-0.220	**0.189**	0.082	**0.147**	0.049
n-Hexyl acetate	0.303	**0.468**	**0.412**	0.125	0.092	**0.219**	**0.170**	0.016
Ethyl esters	-0.021	0.155	0.073	0.276	0.000	0.024	0.005	0.076
Ethyl lactate	-0.032	-0.054	-0.046	0.072	0.001	0.003	0.002	0.005
Ethyl butanoate	0.118	0.116	0.125	0.325	0.014	0.013	0.016	0.106
Ethyl 3-hydroxybutanoate	0.001	0.294	0.159	0.294	0.000	0.087	0.025	0.086
Ethyl hexanoate	0.012	0.151	0.088	0.273	0.000	0.023	0.008	0.075
Ethyl octanoate	-0.101	0.055	-0.024	0.179	0.010	0.003	0.001	0.032
Ethyl decanoate	-0.294	-0.109	-0.214	0.006	0.086	0.012	0.046	0.000
Branched-chain fatty acid ethyl esters	**-0.560**	**-0.445**	**-0.535**	0.154	**0.314**	**0.198**	**0.287**	0.024
Ethyl-2-methylbutanoate	**-0.562**	**-0.433**	**-0.530**	0.099	**0.316**	**0.187**	**0.281**	0.010
Ethyl 3-methylbutanoate	**-0.542**	**-0.445**	**-0.525**	0.205	**0.293**	**0.198**	**0.276**	0.042

Bold values show significant correlation (pearson, α=0.05) with glucose + fructose content

Appendix 2.3.1.5. Correlation matrix and coefficients of esters with nitrogen and glucose + fructose content								
	PAN	**Ammonia**	**YAN**	**Glucose + fructose**	**PAN**	**Ammonia**	**YAN**	**Glucose + fructose**
	Correlation matrix				**R^2**			
Corvina								
Acetate esters	**0.353**	0.237	**0.317**	**-0.537**	0.125	0.056	0.101	0.289
Isoamyl acetate	**0.361**	0.245	**0.326**	**-0.549**	0.131	0.060	0.106	0.301
n-Hexyl acetate	**0.310**	0.192	0.271	-0.136	0.096	0.037	0.074	0.018
2-Phenethyl acetate	0.021	-0.036	-0.004	-0.212	0.000	0.001	0.000	0.045
Branched-chain fatty acid ethyl esters	-0.154	-0.293	-0.225	0.271	0.024	0.086	0.051	0.074
Ethyl-2-methylbutanoate	**-0.500**	**-0.352**	**-0.457**	**0.607**	0.250	0.124	0.209	0.369
Ethyl 3-methylbutanoate	-0.096	-0.259	-0.175	0.204	0.009	0.067	0.031	0.042
Ethyl esters	**0.418**	0.194	**0.336**	**-0.669**	0.174	0.038	0.113	0.448
Ethyl lactate	**0.584**	**0.690**	**0.662**	**-0.506**	0.341	0.476	0.438	0.256
Ethyl butanoate	**0.473**	0.238	**0.389**	**-0.472**	0.224	0.057	0.151	0.222
Ethyl 3-hydroxybutanoate	**0.572**	**0.412**	**0.527**	**-0.852**	0.328	0.170	0.278	0.727
Ethyl hexanoate	**0.340**	0.129	0.261	**-0.556**	0.116	0.017	0.068	0.309
ethyl octanoate	0.265	0.036	0.174	**-0.568**	0.070	0.001	0.030	0.322
Decanoic acid ethyl ester	-0.126	**-0.310**	-0.216	-0.093	0.016	0.096	0.047	0.009
Ethyl cinnamate	0.227	0.274	0.260	-0.225	0.052	0.075	0.068	0.050
Corvinone								
Acetate esters	**0.527**	0.193	**0.415**	-0.230	0.278	0.037	0.172	0.053
Isoamyl acetate	**0.543**	0.211	**0.432**	-0.237	0.295	0.044	0.187	0.056
n-Hexyl acetate	-0.056	-0.206	-0.125	-0.008	0.003	0.043	0.016	0.000
2-Phenethyl acetate	0.009	-0.261	-0.108	0.012	0.000	0.068	0.012	0.000
Branched-chain fatty acid ethyl esters	**-0.585**	**-0.524**	**-0.595**	**0.319**	0.343	0.274	0.354	0.102
Ethyl-2-methylbutanoate	**-0.640**	**-0.687**	**-0.700**	0.276	0.410	0.471	0.491	0.076
Ethyl 3-methylbutanoate	**-0.503**	**-0.364**	**-0.474**	**0.329**	0.253	0.132	0.225	0.108
Ethyl esters	**0.349**	0.145	0.283	**-0.496**	0.122	0.021	0.080	0.246
Ethyl lactate	**0.382**	0.242	**0.345**	**-0.507**	0.146	0.059	0.119	0.257
Ethyl butanoate	0.200	0.177	0.203	-0.128	0.040	0.031	0.041	0.016
Ethyl 3-hydroxybutanoate	**0.510**	0.251	**0.429**	**-0.643**	0.260	0.063	0.184	0.413
Ethyl hexanoate	0.081	-0.019	0.043	-0.182	0.007	0.000	0.002	0.033
ethyl octanoate	**0.298**	0.118	0.238	**-0.472**	0.089	0.014	0.057	0.223
Decanoic acid ethyl ester	-0.107	-0.191	-0.150	-0.127	0.011	0.037	0.023	0.016
Ethyl cinnamate	-0.118	0.108	-0.027	-0.067	0.014	0.012	0.001	0.004

Appendix 2.3.2.1. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2017 fresh Corvina grapes

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	11.78	0.37	10.08	0.65	7.34	0.48	2.92	0.19	7.56	0.49
Ethyl decanoate	0.86	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fatty acids										
3-Methylbutanoic acid	1.64	0.10	1.24	0.06	1.28	0.06	0.89	0.04	1.19	0.06
Hexanoic acid	272.27	10.49	257.62	13.21	264.88	13.59	142.83	7.33	333.94	17.13
Octanoic acid	169.41	84.96	115.04	3.42	119.20	3.55	101.35	3.02	114.37	3.40
Alcohols										
1-Butanol	1.71	0.01	2.59	0.00	0.10	0.00	0.00	0.00	1.51	0.00
Isoamyl alcohol	53.13	1.18	40.38	2.60	5.20	0.33	26.07	1.68	52.52	3.38
Phenylethyl alcohol	65.28	4.35	54.65	0.19	46.27	0.16	41.66	0.15	45.90	0.16
C_6 alcohols										
1-Hexanol	131.85	3.21	71.24	1.05	78.64	1.16	31.10	0.46	139.75	2.05
cis-3-Hexen-1-ol	1.32	0.09	0.60	0.02	0.74	0.03	0.26	0.01	1.07	0.04
trans-3-Hexen-1-ol	42.35	2.39	32.44	0.43	41.93	0.56	18.21	0.24	50.90	0.68
cis-2-Hexen-1-ol	4.51	0.32	1.26	0.07	2.70	0.15	0.93	0.05	3.32	0.18
Terpenes										
α-phellandrene	0.34	0.03	0.35	0.01	0.29	0.01	0.16	0.03	0.26	0.01
Limonene	0.79	0.06	0.57	0.05	0.61	0.12	0.44	0.08	0.86	0.07
p-Cymene	0.31	0.02	0.24	0.01	0.25	0.04	0.21	0.02	0.33	0.03
Terpinolene	0.94	0.03	0.55	0.06	0.55	0.12	0.42	0.00	1.00	0.07
trans-Linaloloxide	0.58	0.01	0.52	0.01	0.37	0.01	0.00	0.00	0.59	0.01
cis-Linaloloxide	0.61	0.00	0.26	0.01	0.41	0.02	0.00	0.00	0.48	0.03
Linalool	11.62	1.27	8.03	0.62	7.16	0.87	6.36	0.93	13.37	0.09
α-Terpineol	2.58	0.13	1.61	0.18	1.70	0.06	1.32	0.06	4.10	0.06
β citronellol	0.96	0.03	0.92	0.04	0.80	0.03	1.44	0.06	0.75	0.03
Nerol	2.19	0.00	2.49	0.13	1.84	0.10	2.14	0.11	2.33	0.12
Geraniol	5.31	0.01	6.26	0.20	4.08	0.13	6.47	0.21	3.08	0.10
Norisoprenoids	26.23		21.77		18.02		18.94		27.12	
3-Hydroxy-β-damascone	0.09	0.01	0.08	0.00	0.11	0.00	0.09	0.00	0.09	0.00
β-Damascenone	2.24	0.06	2.52	0.01	2.17	0.30	1.51	0.28	2.26	0.21
Vitispirane	0.54	0.01	0.20	0.02	0.49	0.14	0.28	0.04	1.68	0.35
TPB	0.02	0.00	0.03	0.00	0.02	0.00	0.01	0.00	0.02	0.00
TDN	0.14	0.01	0.25	0.01	0.17	0.02	0.10	0.02	0.22	0.00
Benzenoids										
Benzaldehyde	4.74	0.25	4.96	0.22	3.41	0.15	4.09	0.18	4.02	0.18
Methyl salycilate	1.41	0.25	0.74	0.13	0.55	0.08	0.72	0.11	0.38	0.00
Benzyl alcohol	42.76	0.64	61.84	1.16	39.34	0.74	51.03	0.96	48.43	0.91
Vanillin	42.69	12.41	33.95	2.53	35.31	2.63	31.91	2.38	47.71	3.55
Ethyl-vanillate	37.61	1.33	65.35	2.61	79.12	3.16	88.16	3.53	55.54	2.22
Eugenol	2.55	0.22	3.54	0.10	2.57	0.07	4.36	0.12	2.94	0.08
2,6-dimethoxy-phenol	4.41	0.19	4.48	0.16	3.92	0.14	4.03	0.14	4.30	0.15
Bound compounds										
Alcohols										
1-Butanol	23.97	0.17	28.24	0.20	23.62	0.17	19.61	0.14	22.82	0.16
Isoamyl alcohol	4.94	0.08	6.93	0.11	2.87	0.04	0.00	0.00	2.37	0.04
Phenylethyl alcohol	29.25	1.53	30.36	1.59	27.90	1.46	20.57	1.08	25.61	1.34
C_6 alcohols										
1-Hexanol	21.91	0.89	17.42	0.71	26.97	1.10	9.94	0.41	17.06	0.69
cis-3-Hexen-1-ol	0.84	0.05	0.71	0.04	0.65	0.04	0.54	0.03	0.77	0.05
trans-3-Hexen-1-ol	3.81	0.21	4.50	0.24	5.45	0.29	2.09	0.11	3.84	0.21
cis-2-Hexen-1-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Terpenes										
Limonene	0.48	0.02	0.41	0.01	0.43	0.02	0.36	0.01	0.43	0.02
p-Cymene	0.16	0.01	0.20	0.01	0.11	0.01	0.12	0.01	0.18	0.01
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	1.86	0.06	0.00	0.00	0.88	0.03	0.52	0.02	0.90	0.03
cis-Linaloloxide	1.58	0.05	0.02	0.00	0.77	0.03	0.61	0.02	1.16	0.04
Linalool	11.50	0.26	6.20	0.14	10.36	0.24	8.17	0.19	7.07	0.16
α-Terpineol	0.74	0.02	0.44	0.01	1.26	0.03	0.66	0.02	0.78	0.02
β citronellol	3.20	0.06	1.58	0.03	1.86	0.04	2.02	0.04	0.00	0.00
Nerol	7.73	0.39	6.40	0.32	8.85	0.44	5.07	0.25	5.35	0.27
Geraniol	15.62	1.13	12.07	0.87	17.04	1.23	12.30	0.89	11.58	0.83
Norisoprenoids										
3-Hydroxy-β-damascone	0.92	0.03	0.77	0.03	0.82	0.03	0.43	0.01	0.53	0.02
Benzenoids										
Benzaldehyde	0.80	0.04	0.57	0.03	0.49	0.03	0.42	0.02	0.55	0.03
Methyl salycilate	0.38	0.02	0.22	0.01	0.25	0.01	0.12	0.01	0.38	0.02
Benzyl alcohol	19.41	1.28	13.68	0.90	17.22	1.13	10.06	0.66	16.36	1.08
Vanillin	3.27	0.04	0.00	0.00	3.52	0.04	2.65	0.03	2.90	0.03
Methyl-vanillate	26.65	1.17	41.69	1.82	21.48	0.94	16.69	0.73	39.09	1.71

Appendix 2.3.2.2. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2017 fresh Corvinone grapes

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	4.76	0.13	5.59	0.36	4.76	0.31	2.52	0.16	3.72	0.24
Ethyl decanoate	0.70	0.00	0.00	0.00	0.00	0.00	0.69	0.02	0.00	0.00
Fatty acids										
3-Methylbutanoic acid	2.57	0.17	1.11	0.05	1.73	0.08	1.07	0.05	5.73	0.27
Hexanoic acid	140.69	1.10	137.10	7.03	136.04	6.98	120.97	6.21	140.02	7.18
Octanoic acid	101.52	7.48	109.29	3.25	114.06	3.40	127.05	3.78	136.02	4.05
Alcohols										
1-Butanol	0.00	0.00	1.63	0.00	0.00	0.00	0.00	0.00	1.05	0.00
Isoamyl alcohol	51.96	0.11	32.84	2.11	54.91	3.53	42.49	2.73	118.24	7.60
Phenylethyl alcohol	45.13	0.48	13.38	0.05	46.55	0.16	17.54	0.06	166.90	0.59
C_6 alcohols										
1-Hexanol	231.22	8.91	104.40	1.53	142.90	2.10	67.35	0.99	90.53	1.33
cis-3-Hexen-1-ol	3.98	0.17	1.33	0.05	1.97	0.08	0.55	0.02	1.60	0.06
trans-3-Hexen-1-ol	27.36	1.30	25.45	0.34	33.48	0.45	14.41	0.19	17.35	0.23
cis-2-Hexen-1-ol	8.96	0.41	5.96	0.32	6.25	0.34	1.25	0.07	4.93	0.26
Terpenes										
α-phellandrene	0.45	0.15	0.22	0.02	0.23	0.03	0.09	0.00	0.16	0.00
Limonene	0.34	0.03	0.23	0.01	0.35	0.05	0.23	0.01	0.42	0.02
p-Cymene	0.16	0.01	0.11	0.01	0.20	0.01	0.12	0.02	0.19	0.01
Terpinolene	0.24	0.02	0.22	0.01	0.20	0.04	0.07	0.00	0.36	0.02
trans-Linaloloxide	0.18	0.01	0.00	0.00	0.68	0.01	0.33	0.00	1.27	0.02
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.25	0.01	0.30	0.02	0.78	0.04
Linalool	2.52	0.13	1.42	0.14	2.02	0.21	1.29	0.18	5.25	0.30
α-Terpineol	0.61	0.08	0.51	0.08	0.52	0.10	0.39	0.07	1.45	0.11
β citronellol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nerol	0.00	0.00	0.00	0.00	0.00	0.00	1.08	0.06	1.17	0.06
Geraniol	1.07	0.07	0.23	0.01	0.52	0.02	0.69	0.02	0.00	0.00
Norisoprenoids										
3-Hydroxy-β-damascone	0.08	0.00	0.09	0.00	0.09	0.00	0.06	0.00	0.06	0.00
β-Damascenone	2.03	0.07	2.84	0.52	3.00	0.19	1.24	0.27	2.66	0.03
Vitispirane	0.48	0.08	0.48	0.04	0.83	0.12	0.64	0.09	2.02	0.05
TPB	0.02	0.00	0.02	0.00	0.02	0.00	0.01	0.01	0.02	0.00
TDN	0.09	0.01	0.14	0.02	0.12	0.01	0.12	0.00	0.16	0.00
Benzenoids										
Benzaldehyde	5.36	0.32	5.05	0.22	5.27	0.23	6.33	0.28	6.68	0.29
Methyl salycilate	2.80	0.39	1.73	0.20	2.03	0.28	1.31	0.19	1.12	0.01
Benzyl alcohol	13.35	0.65	13.87	0.26	15.31	0.29	11.21	0.21	12.99	0.24
Vanillin	36.14	2.69	37.46	2.79	43.21	3.22	33.42	2.49	43.64	3.25
Ethyl-vanillate	53.28	2.13	97.52	3.90	109.34	4.37	146.32	5.85	70.85	2.83
Eugenol	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.02	0.46	0.01
2,6-dimethoxy-phenol	5.50	0.22	4.90	0.17	5.21	0.19	5.42	0.19	4.95	0.18
Bound Compounds										
Alcohols										
1-Butanol	25.03	0.18	20.47	0.15	21.31	0.15	20.40	0.14	22.50	0.16
Isoamyl alcohol	4.44	0.07	0.81	0.01	1.46	0.02	1.48	0.02	7.21	0.11
Phenylethyl alcohol	35.80	1.88	32.98	1.73	28.98	1.52	25.42	1.33	38.80	2.03
C_6 alcohols										
1-Hexanol	24.00	0.98	27.59	1.12	24.08	0.98	12.84	0.52	34.46	1.40
cis-3-Hexen-1-ol	0.65	0.04	0.50	0.03	0.19	0.01	0.64	0.04	0.61	0.04
trans-3-Hexen-1-ol	3.51	0.19	3.57	0.19	3.39	0.18	1.61	0.09	4.22	0.23
cis-2-Hexen-1-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Terpenes										
Limonene	0.43	0.02	0.43	0.02	0.37	0.01	0.48	0.02	0.47	0.02
p-Cymene	0.14	0.01	0.14	0.01	0.14	0.01	0.17	0.01	0.13	0.01
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.37	0.01	0.00	0.00	0.72	0.02
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.28	0.01	0.00	0.00	0.70	0.02
Linalool	3.70	0.09	1.81	0.04	2.04	0.05	1.20	0.03	6.51	0.15
α-Terpineol	0.30	0.01	0.00	0.00	0.20	0.00	0.10	0.00	0.23	0.01
β citronellol	1.42	0.03	1.37	0.03	1.01	0.02	1.06	0.02	1.35	0.03
Nerol	8.39	0.42	8.88	0.44	9.16	0.46	1.01	0.05	9.26	0.46
Geraniol	17.88	1.29	18.92	1.36	21.62	1.56	13.42	0.97	17.79	1.28
Norisoprenoids										
3-Hydroxy-β-damascone	0.95	0.03	1.13	0.04	0.94	0.03	0.41	0.01	1.04	0.04
Benzenoids										
Benzaldehyde	0.93	0.05	0.50	0.03	0.54	0.03	0.47	0.02	0.44	0.02
Methyl salycilate	0.51	0.03	0.55	0.03	0.62	0.03	0.60	0.03	0.50	0.03
Benzyl alcohol	22.78	1.50	16.24	1.07	23.88	1.57	13.42	0.88	13.84	0.91
Vanillin	3.53	0.04	4.20	0.05	3.50	0.04	2.77	0.03	3.70	0.04
Methyl-vanillate	32.82	1.44	50.62	2.21	46.59	2.04	54.17	2.37	27.55	1.20

Appendix 2.3.2.3. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2018 fresh Corvina grapes

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	5.84	0.14	9.28	0.79	11.05	1.61	4.44	0.71	4.05	0.30
Ethyl decanoate	1.42	0.19	1.59	0.72	0.97	0.04	1.16	0.11	0.87	0.05
Fatty acids										
3-Methylbutanoic acid	2.67	0.01	1.00	0.02	2.42	0.12	0.76	0.05	1.30	0.05
Hexanoic acid	15.98	1.61	98.14	4.84	158.04	10.77	20.19	1.41	29.87	0.84
Octanoic acid	176.27	20.65	210.36	5.78	195.23	6.48	162.85	19.43	164.12	18.22
Alcohols										
1-Butanol	2.82	0.46	5.87	0.04	3.30	0.23	2.57	0.28	2.92	0.37
Isoamyl alcohol	676.53	100.83	322.63	10.74	376.20	34.29	267.89	23.74	344.14	13.12
Phenylethyl alcohol	141.74	24.64	102.28	0.89	116.02	10.81	73.20	1.43	106.96	1.12
C_6 alcohols										
1-Hexanol	269.27	47.52	451.14	8.44	432.98	32.43	170.85	7.45	188.35	7.01
cis-3-Hexen-1-ol	2.095	0.05	2.98	0.09	3.20	0.30	1.10	0.04	1.51	0.09
trans-3-Hexen-1-ol	72.645	11.70	143.19	0.35	102.93	13.73	45.83	0.48	44.92	2.06
cis-2-Hexen-1-ol	2.64	0.39	4.66	0.15	6.88	0.67	1.56	0.03	1.47	0.03
Terpenes										
α-phellandrene	1.79	0.13	3.01	0.01	3.26	0.56	2.12	0.19	6.65	0.68
Limonene	0.22	0.03	0.56	0.02	0.69	0.10	0.46	0.03	1.69	0.23
p-Cymene	0.2	0.01	0.29	0.02	0.30	0.02	0.28	0.02	0.52	0.08
Terpinolene	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	0.795	0.02	2.48	0.17	2.13	0.00	1.65	0.05	2.89	0.47
α-Terpineol	0.295	0.04	1.02	0.10	0.92	0.13	0.61	0.01	2.14	0.36
β citronellol	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nerol	2.775	0.02	2	0.00	1.98	0.00	2.10	0.00	1.69	0.04
Geraniol	13.71	0.51	5.76	0.17	4.73	0.66	4.58	0.70	2.95	0.08
Norisoprenoids										
3-Hydroxy-β-damascone	0.01	0.01	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00
β-Damascenone	0.96	0.20	1.88	0.36	1.68	0.20	0.18	0.01	1.83	0.27
Vitispirane	0.035	0.01	0.08	0.01	0.15	0.04	0.01	0.01	0.68	0.12
TPB	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
TDN	0.02	0.01	0.05	0.01	0.07	0.01	0.02	0.00	0.16	0.02
Benzenoids										
Benzaldehyde	4.43	0.42	8.49	1.18	3.09	0.03	2.26	0.43	2.47	0.36
Methyl salycilate	0.14	0.03	0.18	0.02	0.30	0.04	0.55	0.01	0.29	0.04
Benzyl alcohol	112.96	12.52	43.41	1.09	51.54	1.25	42.23	3.35	44.80	6.45
Vanillin	15.05	1.40	10.64	1.53	7.38	0.34	10.98	1.64	11.51	1.36
Ethyl-vanillate	132.67	16.35	57.97	1.77	49.42	3.71	148.87	1.17	47.52	4.52
Eugenol	1.39	0.16	1.58	0.14	1.49	0.23	0.00	0.00	1.00	0.08
2,6-dimethoxy-phenol	7.62	0.06	5.91	0.84	4.92	0.32	5.10	0.06	5.20	0.31
Bound Compounds										
Alcohols										
1-Butanol	0.53	0.10	0.80	0.03	1.56	0.08	0.48	0.03	0.42	0.57
Isoamyl alcohol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phenylethyl alcohol	16.44	0.00	24.40	0.03	27.63	0.05	17.10	0.01	27.21	0.03
C_6 alcohols										
1-Hexanol	7.89	0.02	23.43	0.04	20.26	0.17	14.37	0.03	27.20	0.15
cis-3-Hexen-1-ol	0.00	0.00	0.00	0.00	0.05	0.07	0.00	0.00	0.36	0.51
trans-3-Hexen-1-ol	0.74	0.05	0.83	0.18	2.60	0.05	1.48	0.04	3.14	0.03
cis-2-Hexen-1-ol	3.40	0.09	7.98	0.57	6.94	0.09	5.16	0.04	7.98	0.11
Terpenes										
Limonene	0.47	0.04	0.45	0.01	0.48	0.01	0.49	0.02	0.52	0.01
p-Cymene	0.07	0.00	0.08	0.01	0.07	0.00	0.06	0.00	0.07	0.01
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	1.21	0.29	5.81	0.33	6.25	0.03	10.99	0.01	9.26	0.00
α-Terpineol	0.21	0.01	0.62	0.01	0.62	0.04	0.63	0.02	1.08	0.04
β citronellol	3.35	0.00	1.04	0.14	0.88	0.01	1.75	0.03	1.12	0.04
Nerol	5.54	0.17	6.55	0.14	5.89	0.08	6.46	0.14	7.23	0.35
Geraniol	22.46	0.12	19.89	0.47	18.66	0.15	18.95	0.33	23.23	0.01
Norisoprenoids										
3-Oxo-α-ionol	0.51	0.01	1.12	0.01	1.02	0.03	0.68	0.03	1.19	0.03
3-Hydroxy-β-damascone	0.24	0.01	0.57	0.01	0.43	0.01	0.18	0.00	0.57	0.01
Benzenoids										
Benzaldehyde	0.57	0.04	0.57	0.04	0.43	0.01	0.40	0.00	0.67	0.01
Methyl salycilate	0.05	0.01	0.11	0.00	0.27	0.01	0.46	0.01	0.37	0.00
Benzyl alcohol	22.94	3.90	11.46	0.83	18.68	0.07	10.37	0.64	21.38	0.42
Vanillin	4.17	0.17	4.13	0.25	3.65	0.01	3.39	0.39	4.03	0.40
Methyl-vanillate	42.46	1.39	34.25	0.42	24.15	1.04	13.45	0.83	30.35	1.30

Appendix 2.3.2.4. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2018 fresh Corvinone grapes

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	13.83	2.47	4.60	0.14	5.58	0.76	4.40	0.13	3.81	0.18
Ethyl decanoate	7.10	0.30	0.86	0.08	1.72	0.02	1.13	0.04	0.90	0.20
Fatty acids										
3-Methylbutanoic acid	1.64	0.19	1.37	0.02	1.30	0.04	0.85	0.00	3.80	0.17
Hexanoic acid	36.73	3.27	16.88	1.14	50.12	4.89	17.99	0.16	31.70	1.14
Octanoic acid	450.21	67.59	192.72	1.61	298.10	24.33	299.79	3.24	263.50	8.14
Alcohols										
1-Butanol	3.07	0.01	2.41	0.21	2.93	0.23	1.22	0.02	1.08	0.09
Isoamyl alcohol	1106.23	55.15	293.13	7.64	376.50	14.47	519.63	8.77	191.99	36.76
Phenylethyl alcohol	109.89	2.55	23.39	0.72	65.15	1.21	172.88	5.13	53.78	2.46
C_6 alcohols										
1-Hexanol	192.45	5.64	185.82	3.22	377.10	11.22	121.32	1.43	287.71	11.00
cis-3-Hexen-1-ol	2.645	0.26	3.80	0.53	8.48	0.06	2.20	0.04	5.29	0.52
trans-3-Hexen-1-ol	24.16	2.31	21.32	1.22	32.64	0.08	16.04	0.19	32.28	1.53
cis-2-Hexen-1-ol	3.14	0.19	4.02	0.18	8.30	0.21	3.02	0.04	6.40	0.30
Terpenes										
α-phellandrene	0.13	0.01	0.90	0.06	0.51	0.13	0.83	0.16	2.74	0.11
Limonene	0.34	0.01	0.28	0.01	0.13	0.01	0.25	0.07	0.72	0.03
p-Cymene	0.255	0.04	0.23	0.04	0.04	0.01	0.19	0.03	0.34	0.03
Terpinolene	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	1.22	0.01	0.76	0.08	0.72	0.04	0.74	0.01	1.42	0.16
α-Terpineol	0.35	0.03	0.00	0.00	0.25	0.01	0.16	0.01	0.85	0.01
β citronellol	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nerol	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.01
Geraniol	1.475	0.18	1.02	0.16	1.27	0.13	0.60	0.04	0.40	0.01
Norisoprenoids										
3-Hydroxy-β-damascone	0.03	0.00	0.03	0.00	1.09	0.13	0.00	0.00	0.00	0.00
β-Damascenone	3.57	0.16	3.61	0.83	2.38	0.24	0.61	0.07	1.29	0.16
Vitispirane	0.235	0.01	0.30	0.07	0.09	0.01	0.10	0.01	1.13	0.07
TPB	0.01	0.00	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.00
TDN	0.09	0.00	0.09	0.01	0.04	0.01	0.03	0.01	0.18	0.04
Benzenoids										
Benzaldehyde	3.96	0.45	2.00	0.33	1.40	0.21	1.41	0.03	1.71	0.22
Methyl salycilate	0.30	0.03	0.16	0.03	0.18	0.02	0.10	0.01	0.18	0.04
Benzyl alcohol	16.04	2.38	11.87	2.45	8.44	0.20	4.21	0.16	4.38	0.40
Vanillin	21.62	3.42	13.03	1.87	14.02	2.76	12.51	1.26	12.01	1.42
Ethyl-vanillate	136.31	19.64	109.17	2.83	157.63	0.55	124.66	11.54	134.27	2.03
Eugenol	0.23	0.01	0.22	0.02	0.25	0.01	0.25	0.03	0.23	0.02
2,6-dimethoxy-phenol	5.44	0.98	5.70	0.78	5.42	0.34	5.24	0.33	6.11	0.40
Bound Compounds										
Alcohols										
1-Butanol	0.86	0.22	2.16	0.13	4.26	0.18	1.13	0.00	2.39	0.55
Isoamyl alcohol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phenylethyl alcohol	19.76	0.13	22.06	0.05	24.87	0.09	18.82	2.12	31.22	1.58
C_6 alcohols										
1-Hexanol	21.17	0.25	34.85	0.06	47.04	0.02	21.99	0.73	32.62	4.97
cis-3-Hexen-1-ol	0.11	0.02	0.17	0.02	0.35	0.00	0.11	0.01	0.26	0.02
trans-3-Hexen-1-ol	0.75	0.07	2.32	0.09	2.77	0.09	1.50	0.14	3.39	0.27
cis-2-Hexen-1-ol	12.66	0.62	18.83	0.06	22.63	0.52	11.66	0.97	14.03	2.42
Terpenes										
Limonene	0.53	0.04	0.54	0.01	0.48	0.02	0.48	0.03	0.57	0.04
p-Cymene	0.07	0.00	0.06	0.00	0.07	0.00	0.07	0.01	0.11	0.01
Terpinolene	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	4.70	0.16	2.26	0.05	1.64	0.02	3.18	0.06	3.34	0.31
α-Terpineol	0.34	0.01	0.12	0.03	0.16	0.01	0.20	0.03	0.19	0.01
β citronellol	0.84	0.08	0.85	0.05	0.99	0.03	2.15	0.13	0.93	0.04
Nerol	9.85	0.06	10.19	0.13	12.23	0.03	13.99	0.17	8.39	0.41
Geraniol	27.62	0.56	30.73	0.18	34.32	0.04	28.15	0.69	20.39	0.83
Norisoprenoids										
3-Oxo-α-ionol	1.14	0.00	1.24	0.01	1.13	0.00	1.18	0.48	1.43	0.15
3-Hydroxy-β-damascone	0.64	0.00	0.54	0.00	0.30	0.01	0.31	0.01	0.65	0.07
Benzenoids										
Benzaldehyde	0.53	0.10	0.67	0.00	0.46	0.00	0.40	0.00	0.58	0.04
Methyl salycilate	0.18	0.00	0.19	0.01	0.16	0.00	0.24	0.04	0.40	0.05
Benzyl alcohol	11.23	0.31	10.96	1.75	16.32	2.30	10.72	2.52	23.73	1.06
Vanillin	4.37	0.57	4.30	0.32	6.37	0.21	4.23	0.32	3.86	0.26
Methyl-vanillate	45.36	1.11	39.36	3.79	47.79	0.99	38.11	0.32	23.85	1.10

Appendix 2.3.2.5. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2019 fresh Corvina grapes

	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	44.58	0.90	10.53	0.21	18.04	0.36	42.36	0.86	20.40	0.41
Ethyl decanoate	6.53	0.33	0.70	0.04	0.68	0.03	9.07	0.46	0.95	0.05
Fatty acids										
3-Methylbutanoic acid	3.64	0.22	0.71	0.04	3.84	0.23	0.63	0.04	1.42	0.09
Hexanoic acid	133.80	0.47	198.75	0.70	171.52	0.60	185.95	0.66	175.58	0.62
Octanoic acid	423.17	12.60	96.27	2.87	108.30	3.22	630.66	18.77	131.89	3.93
Alcohols										
1-Butanol	3.74	0.21	3.16	0.17	2.61	0.14	2.33	0.13	1.53	0.08
Isoamyl alcohol	1037.71	74.80	87.68	6.32	105.96	7.64	1156.42	83.36	579.24	41.76
Phenylethyl alcohol	218.73	5.32	82.96	2.02	111.52	2.71	130.83	3.18	157.27	3.83
C_6 alcohols										
1-Hexanol	494.97	9.58	207.03	4.01	122.57	2.37	174.33	3.37	395.70	7.66
cis-3-Hexen-1-ol	3.65	0.09	1.73	0.04	1.29	0.03	1.16	0.03	2.88	0.07
trans-3-Hexen-1-ol	39.53	0.17	28.66	0.12	15.41	0.07	15.08	0.06	29.43	0.12
cis-2-Hexen-1-ol	4.76	0.15	2.99	0.09	1.25	0.04	2.37	0.08	3.46	0.11
Terpenes										
α-phellandrene	0.38	0.04	0.39	0.06	0.32	0.04	0.22	0.01	0.38	0.11
Limonene	0.29	0.00	0.43	0.00	0.43	0.00	0.53	0.00	0.63	0.00
p-Cymene	0.21	0.00	0.47	0.08	0.41	0.02	0.21	0.04	0.52	0.09
Terpinolene	0.24	0.03	1.83	0.23	1.55	0.03	0.48	0.01	2.81	0.26
trans-Linaloloxide	0.49	0.03	0.25	0.02	0.31	0.02	0.00	0.00	0.41	0.03
cis-Linaloloxide	0.27	0.00	0.24	0.00	0.27	0.00	0.00	0.00	0.40	0.01
Linalool	0.60	0.04	6.47	0.43	5.50	0.37	1.55	0.10	9.56	0.64
α-Terpineol	0.48	0.07	5.11	1.43	5.32	0.52	1.33	0.12	9.14	0.47
β citronellol	0.00	0.00	0.75	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Nerol	2.34	0.06	2.01	0.06	1.61	0.04	2.07	0.06	1.92	0.05
Geraniol	7.56	0.50	5.25	0.35	3.49	0.23	4.95	0.33	4.00	0.27
Norisoprenoids										
3-Hydroxy-β-damascone	0.03	0.00	0.02	0.00	0.03	0.00	0.04	0.00	0.06	0.00
β-Damascenone	1.94	0.22	2.71	0.47	2.27	0.15	1.18	0.16	4.58	0.40
Vitispirane	0.56	0.06	1.16	0.04	1.08	0.03	0.25	0.01	1.79	0.01
TPB	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.02	0.00
TDN	0.10	0.02	0.20	0.04	0.17	0.00	0.12	0.03	0.44	0.01
Benzenoids										
Benzaldehyde	3.95	0.01	2.37	0.00	9.43	0.01	6.72	0.01	4.34	0.01
Methyl salycilate	0.26	0.04	0.26	0.01	0.32	0.00	0.32	0.04	0.25	0.04
Benzyl alcohol	57.35	1.71	35.57	1.06	27.16	0.81	85.56	2.55	33.71	1.00
Vanillin	13.12	0.75	9.03	0.52	8.41	0.48	7.92	0.45	12.08	0.69
Ethyl-vanillate	73.02	1.57	41.42	0.89	41.46	0.89	86.36	1.86	66.38	1.43
Eugenol	1.12	0.08	3.62	0.25	1.65	0.11	2.76	0.19	1.85	0.13
2,6-dimethoxy-phenol	3.50	0.23	3.55	0.23	3.64	0.24	3.66	0.24	3.70	0.24
Bound Compounds										
Alcohols										
1-Butanol	0.77	0.04	0.00	0.00	0.52	0.03	0.96	0.05	1.00	0.06
Isoamyl alcohol	4.75	0.23	3.50	0.17	2.58	0.12	6.25	0.30	11.95	0.57
Phenylethyl alcohol	26.94	0.23	25.65	0.22	30.48	0.26	24.35	0.21	38.67	0.33
C_6 alcohols										
1-Hexanol	17.42	0.10	26.32	0.15	23.70	0.13	14.84	0.08	41.50	0.24
cis-3-Hexen-1-ol	0.42	0.01	0.48	0.01	0.34	0.01	0.42	0.01	0.41	0.01
trans-3-Hexen-1-ol	1.75	0.05	4.05	0.11	4.30	0.12	1.05	0.03	6.58	0.18
cis-2-Hexen-1-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Terpenes										
Limonene	0.84	0.05	0.81	0.05	0.33	0.02	0.67	0.04	0.82	0.05
p-Cymene	0.07	0.00	0.09	0.00	0.06	0.00	0.08	0.00	0.08	0.00
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.35	0.02	1.15	0.06	0.89	0.05	0.00	0.00	1.22	0.06
cis-Linaloloxide	0.50	0.01	1.14	0.03	1.33	0.04	0.00	0.00	1.36	0.04
Linalool	1.50	0.08	18.13	1.01	13.16	0.74	4.18	0.23	35.86	2.00
α-Terpineol	0.35	0.02	1.47	0.10	1.25	0.09	0.32	0.02	2.15	0.15
β citronellol	4.27	0.14	2.06	0.07	1.51	0.05	1.16	0.04	1.41	0.05
Nerol	6.16	0.30	7.07	0.34	8.03	0.39	3.89	0.19	7.79	0.38
Geraniol	23.08	0.43	17.74	0.33	20.08	0.38	9.81	0.18	18.54	0.35
Norisoprenoids										
3-Hydroxy-β-damascone	0.39	0.01	0.43	0.02	0.45	0.02	0.22	0.01	0.78	0.03
Benzenoids										
Benzaldehyde	0.46	0.01	0.38	0.01	0.41	0.01	0.48	0.01	0.55	0.01
Methyl salycilate	0.17		0.21		0.34		0.21		0.38	
Benzyl alcohol	18.72	0.25	14.20	0.19	14.63	0.20	18.29	0.25	23.34	0.32
Vanillin	5.49	0.00	3.33	0.00	3.19	0.00	3.41	0.00	3.28	0.00
Methyl-vanillate	53.00	0.45	25.56	0.22	25.16	0.21	9.32	0.08	17.18	0.14

Appendix 2.3.2.6. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2019 fresh Corvinone grapes

	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	7.61	0.15	3.91	0.08	16.07	0.32	3.00	0.06	5.89	0.12
Ethyl decanoate	0.70	0.04	0.72	0.04	0.67	0.03	0.65	0.03	0.65	0.03
Fatty acids										
3-Methylbutanoic acid	0.72	0.04	1.54	0.09	0.91	0.06	0.71	0.04	2.00	0.12
Hexanoic acid	71.66	0.25	70.10	0.25	80.79	0.28	46.51	0.16	69.72	0.25
Octanoic acid	97.52	2.90	97.94	2.92	100.93	3.00	94.38	2.81	99.30	2.96
Alcohols										
1-Butanol	0.00	0.00	1.60	0.09	0.00	0.00	0.00	0.00	1.39	0.08
Isoamyl alcohol	54.28	3.91	44.21	3.19	48.37	3.49	21.59	1.56	144.54	10.42
Phenylethyl alcohol	23.06	0.56	24.70	0.60	29.51	0.72	15.13	0.37	161.45	3.93
C_6 alcohols										
1-Hexanol	168.15	3.25	233.33	4.52	345.11	6.68	120.34	2.33	277.97	5.38
cis-3-Hexen-1-ol	2.69	0.07	5.02	0.13	7.54	0.19	2.47	0.06	5.33	0.14
trans-3-Hexen-1-ol	6.31	0.03	13.53	0.06	15.76	0.07	6.82	0.03	12.07	0.05
cis-2-Hexen-1-ol	3.11	0.10	5.45	0.17	6.78	0.22	3.64	0.12	6.62	0.21
Terpenes										
α-phellandrene	0.23	0.04	0.10	0.03	0.21	0.05	0.16	0.01	0.30	0.04
Limonene	0.32	0.00	0.40	0.00	0.46	0.00	0.48	0.00	0.76	0.01
p-Cymene	0.38	0.04	0.18	0.01	0.14	0.00	0.16	0.01	0.29	0.01
Terpinolene	0.79	0.03	0.31	0.05	0.30	0.05	0.28	0.01	0.92	0.01
trans-Linaloloxide	0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	2.45	0.16	1.35	0.09	1.17	0.08	1.00	0.07	3.88	0.26
α-Terpineol	3.24	0.16	1.11	0.08	1.06	0.06	0.76	0.04	3.65	0.09
β citronellol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nerol	1.19	0.03	1.03	0.03	0.98	0.03	1.20	0.03	1.04	0.03
Geraniol	0.21	0.01	0.26	0.02	0.00	0.00	0.12	0.01	0.83	0.06
Norisoprenoids										
3-Hydroxy-β-damascone	0.02	0.00	0.02	0.00	0.03	0.00	0.02	0.00	0.03	0.00
β-Damascenone	2.81	0.65	2.36	0.38	2.89	0.04	1.75	0.14	2.99	0.01
Vitispirane	4.82	0.96	1.16	0.14	0.58	0.11	0.48	0.03	2.02	0.10
TPB	0.01	0.00	0.01	0.00	0.02	0.00	0.01	0.00	0.01	0.01
TDN	0.29	0.03	0.11	0.05	0.10	0.02	0.10	0.01	0.20	0.02
Benzenoids										
Benzaldehyde	2.74	0.00	2.16	0.00	2.38	0.00	2.44	0.00	1.84	0.00
Methyl salycilate	0.43	0.05	0.52	0.18	1.12	0.23	0.52	0.01	0.44	0.02
Benzyl alcohol	3.67	0.11	4.52	0.13	8.71	0.26	6.64	0.20	12.66	0.38
Vanillin	9.19	0.53	10.59	0.61	9.87	0.57	9.62	0.55	8.30	0.48
Ethyl-vanillate	46.00	0.99	55.75	1.20	72.68	1.57	74.72	1.61	36.61	0.79
Eugenol	0.00	0.00	0.32	0.02	0.45	0.03	0.31	0.02	0.00	0.00
2,6-dimethoxy-phenol	3.86	0.26	3.98	0.26	3.92	0.26	4.08	0.27	4.06	0.27
z										
Alcohols										
1-Butanol	1.84	0.10	0.99	0.05	1.90	0.10	1.21	0.07	0.87	0.05
Isoamyl alcohol	4.92	0.23	1.64	0.08	3.89	0.18	1.36	0.06	6.06	0.29
Phenylethyl alcohol	28.10	0.24	25.91	0.22	33.49	0.28	29.27	0.25	33.33	0.28
C_6 alcohols										
1-Hexanol	31.32	0.18	32.60	0.19	27.86	0.16	29.50	0.17	41.07	0.23
cis-3-Hexen-1-ol	0.34	0.01	0.43	0.01	0.38	0.01	0.38	0.01	0.39	0.01
trans-3-Hexen-1-ol	2.39	0.07	3.08	0.08	3.02	0.08	2.31	0.06	3.75	0.10
cis-2-Hexen-1-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Terpenes										
Limonene	0.75	0.04	0.37	0.02	0.67	0.04	0.63	0.04	0.55	0.03
p-Cymene	0.08	0.00	0.07	0.00	0.09	0.00	0.07	0.00	0.08	0.00
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.39	0.02	0.57	0.03	0.67	0.04	0.00	0.00	0.53	0.03
cis-Linaloloxide	0.32	0.01	0.28	0.01	0.52	0.01	0.00	0.00	0.38	0.01
Linalool	5.31	0.30	4.50	0.25	6.71	0.38	6.95	0.39	12.96	0.72
α-Terpineol	0.37	0.03	0.27	0.02	0.22	0.02	0.27	0.02	0.59	0.04
β citronellol	1.26	0.04	1.55	0.05	1.68	0.06	1.03	0.03	1.18	0.04
Nerol	11.91	0.58	11.61	0.56	10.10	0.49	8.91	0.43	9.96	0.48
Geraniol	33.34	0.63	25.92	0.49	22.86	0.43	19.91	0.37	24.42	0.46
Norisoprenoids										
3-Hydroxy-β-damascone	0.52	0.02	0.63	0.02	0.96	0.04	0.73	0.03	0.60	0.02
Benzenoids										
Benzaldehyde	0.43	0.01	0.31	0.01	0.44	0.01	0.57	0.01	0.43	0.01
Methyl salycilate	0.28		0.24		0.57		0.37		0.39	
Benzyl alcohol	14.02	0.19	14.09	0.19	25.04	0.34	17.61	0.24	20.23	0.27
Vanillin	3.88	0.00	4.10	0.00	3.79	0.00	3.23	0.00	3.14	0.00
Methyl-vanillate	56.09	0.47	24.82	0.21	40.77	0.34	21.57	0.18	17.75	0.15

Appendix 2.3.2.7. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2017 withered Corvina grapes

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	10.75	0.15	14.09	0.70	7.43	0.40	0.03	0.00	4.33	0.18
Ethyl decanoate	1.08	0.04	0.81	0.00	0.86	0.03	1.09	0.02	0.56	0.00
Fatty acids										
3-Methylbutanoic acid	5.89	0.14	7.42	0.40	2.81	0.06	5.80	0.30	2.34	0.05
Hexanoic acid	420.70	10.91	323.39	14.40	177.75	7.37	210.90	7.96	259.25	9.47
Octanoic acid	158.57	2.38	135.07	4.80	172.81	7.95	148.09	2.79	76.78	3.88
Alcohols										
1-Butanol	5.72	0.09	3.39	0.03	6.05	0.00	14.99	0.45	0.33	0.01
Isoamyl alcohol	252.44	7.10	809.48	36.62	532.29	17.28	675.23	23.48	310.52	11.95
Phenylethyl alcohol	238.41	11.33	261.01	12.48	90.34	4.09	107.73	3.51	51.76	1.57
C_6 alcohols										
1-Hexanol	198.71	10.68	181.78	3.91	134.06	0.66	190.35	2.31	175.19	6.40
cis-3-Hexen-1-ol	19.68	1.04	30.68	1.11	11.46	0.15	26.07	0.76	11.61	0.31
trans-3-Hexen-1-ol	1.85	0.04	1.52	0.06	1.87	0.02	2.07	0.12	4.58	0.02
cis-2-Hexen-1-ol	39.72	0.06	24.44	1.27	34.27	0.97	44.59	1.75	38.99	1.53
Terpenes										
α-Phellandrene	1.18	0.23	3.02	0.53	2.20	0.09	1.60	0.30	8.91	0.16
Limonene	4.43	0.19	0.90	0.15	0.95	0.15	0.74	0.09	4.31	0.19
p-Cymene	4.51	0.08	0.34	0.11	0.58	0.09	0.34	0.05	1.14	0.07
Terpinolene	0.85	0.06	0.35	0.00	0.51	0.01	0.28	0.06	1.88	0.01
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	1.16	0.01	1.42	0.06	1.45	0.08	1.40	0.07	0.04	0.00
Linalool	3.10	0.16	4.25	0.02	3.72	0.04	1.96	0.01	10.05	0.65
α-Terpineol	1.20	0.06	1.16	0.06	1.71	0.33	0.73	0.04	3.39	0.17
β citronellol	2.02	0.42	2.05	0.45	0.99	0.16	0.98	0.14	0.00	0.00
Nerol	6.30	0.42	0.38	0.03	0.19	0.01	0.00	0.00	0.51	0.03
Geraniol	6.86	0.03	5.29	0.19	2.24	0.07	5.95	0.09	5.52	0.09
Norisoprenoids										
3-Hydroxy-β-damascone	0.17	0.01	0.37	0.01	0.11	0.01	0.13	0.01	0.24	0.01
β-Damascenone	2.51	0.52	2.12	0.13	4.19	0.40	2.89	0.22	4.29	0.11
Vitispirane	0.90	0.13	0.11	0.02	1.38	0.04	0.53	0.05	0.57	0.04
TPB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TDN	0.29	0.01	0.06	0.00	0.22	0.00	0.11	0.01	0.28	0.01
Benzenoids										
Benzaldehyde	19.21	0.98	9.25	0.48	5.32	0.14	6.79	0.29	7.00	0.06
Methyl salycilate										
Benzyl alcohol	51.40	1.91	114.06	5.42	40.57	1.20	123.74	5.75	82.92	4.29
Vanillin	37.27	0.86	48.92	2.60	39.96	0.98	45.55	0.62	48.84	0.99
Ethyl-vanillate	72.43	2.79	122.16	5.68	47.86	2.00	55.18	0.71	47.25	0.91
Eugenol	1.92	0.10	4.75	0.25	2.36	0.07	3.95	0.09	2.31	0.01
Bound Compounds										
Alcohols										
1-Butanol	1.36	0.06	2.19	0.05	1.28	0.03	1.80	0.04	1.21	0.02
Isoamyl alcohol	11.65	0.56	29.41	1.26	20.64	0.61	9.91	0.12	18.89	0.33
Phenylethyl alcohol	29.18	0.29	45.27	1.32	23.12	0.07	25.75	0.07	28.30	0.32
C_6 alcohols										
1-Hexanol	23.98	0.26	38.13	2.05	26.22	0.22	33.87	1.78	29.65	0.58
cis-3-Hexen-1-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.01	0.03	0.00
trans-3-Hexen-1-ol	1.54	0.07	3.30	0.13	0.00	0.00	1.96	0.05	2.04	0.09
cis-2-Hexen-1-ol	14.53	0.78	13.79	0.67	15.10	0.06	14.26	0.28	14.14	0.06
Terpenes										
Limonene	0.14	0.01	0.19	0.01	0.00	0.00	0.08	0.00	0.14	0.00
p-Cymene	0.06	0.00	0.08	0.00	0.00	0.00	0.06	0.00	0.09	0.00
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.00	0.00	0.44	0.02	0.00	0.00	0.01	0.00	0.55	0.02
cis-Linaloloxide	0.36	0.02	0.55	0.02	0.00	0.00	0.24	0.01	0.91	0.00
Linalool	1.67	0.09	6.07	0.10	1.59	0.03	1.68	0.01	9.68	0.26
α-Terpineol	0.50	0.02	1.09	0.01	0.83	0.01	0.33	0.00	1.63	0.03
β citronellol	2.44	0.13	1.44	0.06	0.00	0.00	1.07	0.01	1.79	0.03
Nerol	4.09	0.18	4.51	0.15	3.62	0.00	6.07	0.33	6.10	0.04
Geraniol	13.16	0.11	12.53	0.59	9.13	0.07	21.31	0.22	15.17	0.18
Norisoprenoids										
3-Oxo-α-ionol	0.33	0.01	0.31	0.01	0.01	0.00	0.31	0.02	0.31	0.01
3-Hydroxy-β-damascone	0.25	0.01	0.42	0.01	0.33	0.01	0.40	0.02	0.34	0.00
Benzenoids										
Benzaldehyde	0.01	0.00	0.79	0.04	0.49	0.01	0.47	0.02	0.66	0.03
Methyl salycilate	<LOQ		<LOQ		<LOQ		<LOQ		<LOQ	
Benzyl alcohol	16.35	0.93	23.40	1.38	19.61	0.96	12.84	0.31	14.38	0.02
Vanillin	4.05	0.13	4.90	0.23	4.65	0.10	4.53	0.24	4.80	0.02
Methyl-vanillate	34.83	0.15	39.60	1.04	26.14	0.04	40.03	1.38	34.51	1.41

Appendix 2.3.2.8. Concentration (µg/L) and standard deviation (± µg/L) of free and bound volatile compounds of 2017 withered Corvinone grapes

	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	8.75	0.30	4.59	0.05	5.35	0.15	6.83	0.36	3.71	0.17
Ethyl decanoate	1.68	0.09	0.82	0.01	0.85	0.04	0.52	0.02	0.00	0.00
Fatty acids										
3-Methylbutanoic acid	9.19	0.02	12.74	0.39	2.92	0.17	4.95	0.03	1.40	0.06
Hexanoic acid	168.24	0.60	200.39	5.83	217.60	10.26	198.96	6.86	205.63	10.24
Octanoic acid	310.70	14.45	146.34	2.76	157.38	4.89	149.70	1.92	123.64	1.99
Alcohols										
1-Butanol	4.08	0.21	4.02	0.17	3.68	0.07	0.15	0.00	4.25	0.02
Isoamyl alcohol	916.22	29.13	218.07	10.29	183.44	2.09	562.35	18.64	242.16	4.23
Phenylethyl alcohol	127.55	2.31	68.30	3.30	48.15	2.30	140.46	2.11	31.95	0.45
C_6 alcohols										
1-Hexanol	289.03	4.96	114.95	1.31	140.48	4.75	317.70	4.08	182.82	6.90
cis-3-Hexen-1-ol	6.82	0.06	4.77	0.06	5.57	0.05	8.99	0.30	6.70	0.12
trans-3-Hexen-1-ol	4.48	0.21	2.08	0.08	2.65	0.10	5.92	0.20	4.06	0.07
cis-2-Hexen-1-ol	50.39	0.21	28.79	0.84	1.15	0.01	117.81	5.63	50.22	1.04
Terpenes										
α-Phellandrene	2.91	0.15	0.41	0.01	1.19	0.01	0.92	0.15	5.25	0.35
Limonene	1.15	0.30	0.97	0.11	0.41	0.06	1.28	0.10	2.21	0.32
p-Cymene	0.42	0.03	0.49	0.09	0.21	0.01	0.50	0.04	0.82	0.08
Terpinolene	0.50	0.08	0.23	0.04	0.23	0.02	0.33	0.01	1.06	0.22
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.48	0.01	0.57	0.00	1.36	0.05	0.00	0.00	0.00	0.00
Linalool	3.74	0.08	1.27	0.11	2.08	0.01	1.72	0.11	7.44	0.45
α-Terpineol	1.56	0.33	0.35	0.07	0.60	0.15	0.52	0.06	2.25	0.35
β citronellol	0.56	0.06	0.97	0.12	0.72	0.13	0.88	0.14	0.43	0.00
Nerol	0.56	0.06	1.20	0.04	0.52	0.04	0.86	0.03	0.31	0.01
Geraniol	1.33	0.05	0.75	0.00	1.11	0.04	2.61	0.14	1.58	0.01
Norisoprenoids										
3-Hydroxy-β-damascone	0.12	0.00	0.12	0.01	0.11	0.00	0.23	0.01	0.18	0.00
β-Damascenone	3.75	0.50	2.69	0.55	5.45	0.35	3.38	0.52	4.77	0.36
Vitispirane	0.72	0.04	0.99	0.19	1.02	0.04	1.25	0.18	1.06	0.08
TPB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TDN	0.15	0.01	0.17	0.04	0.17	0.00	0.21	0.01	0.24	0.01
Benzenoids										
Benzaldehyde	5.24	0.07	5.66	0.11	5.72	0.08	4.29	0.02	4.12	0.08
Methyl salycilate										
Benzyl alcohol	14.24	0.42	16.19	0.33	18.20	0.86	20.99	1.11	31.81	0.97
Vanillin	40.96	0.46	40.83	1.57	49.45	1.10	51.18	1.78	47.23	0.50
Ethyl-vanillate	44.51	1.42	77.34	0.54	60.82	0.64	70.53	1.06	56.11	1.78
Eugenol	0.22	0.01	0.69	0.03	0.00	0.00	0.00	0.00	1.07	0.04
Bound Compounds										
Alcohols										
1-Butanol	2.24	0.12	3.22	0.07	3.71	0.16	4.00	0.11	2.28	0.06
Isoamyl alcohol	26.11	0.74	23.44	1.17	19.51	1.00	16.82	0.91	23.09	0.61
Phenylethyl alcohol	41.59	1.74	43.89	1.37	35.04	1.61	28.06	1.06	31.53	1.40
C_6 alcohols										
1-Hexanol	51.41	2.39	67.43	1.11	63.48	0.31	45.88	1.55	44.54	1.32
cis-3-Hexen-1-ol	0.41	0.00	0.44	0.01	0.00	0.00	0.35	0.02	0.32	0.01
trans-3-Hexen-1-ol	2.81	0.01	4.89	0.23	3.89	0.22	2.62	0.11	3.34	0.09
cis-2-Hexen-1-ol	14.08	0.38	13.63	0.44	14.05	0.44	13.32	0.49	14.51	0.54
Terpenes										
Limonene	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00
p-Cymene	0.09	0.00	0.06	0.00	0.05	0.00	0.09	0.00	0.09	0.00
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	3.82	0.05	1.45	0.00	1.95	0.04	1.46	0.04	4.51	0.04
α-Terpineol	0.55	0.03	0.40	0.01	0.25	0.01	0.22	0.00	0.57	0.02
β citronellol	2.89	0.02	1.54	0.05	2.45	0.00	1.27	0.07	1.49	0.02
Nerol	10.84	0.11	9.01	0.37	7.04	0.14	9.42	0.38	10.00	0.51
Geraniol	39.00	1.76	30.74	0.84	27.09	0.64	28.63	1.40	30.56	0.70
Norisoprenoids										
3-Oxo-α-ionol	1.23	0.02	0.73	0.02	0.30	0.02	0.54	0.01	0.45	0.00
3-Hydroxy-β-damascone	0.64	0.03	0.74	0.03	0.73	0.03	0.56	0.01	0.59	0.01
Benzenoids										
Benzaldehyde	0.46	0.02	0.47	0.01	0.41	0.02	0.51	0.00	0.60	0.03
Methyl salycilate	<LOQ		<LOQ		<LOQ		<LOQ		<LOQ	
Benzyl alcohol	25.73	0.47	25.07	0.52	27.55	0.46	19.28	0.38	18.40	0.54
Vanillin	4.64	0.21	5.22	0.21	5.26	0.11	5.67	0.28	5.40	0.09
Methyl-vanillate	41.40	1.87	69.53	2.40	38.70	0.61	59.19	0.66	50.68	0.58

Appendix 2.3.2.9. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2018 withered Corvina grapes

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	7.09	0.28	12.39	1.38	16.55	0.95	7.24	0.35	8.13	1.46
Ethyl decanoate	1.86	0.20	2.27	0.45	6.02	0.33	1.42	0.02	2.83	1.10
Fatty acids										
3-Methylbutanoic acid	12.31	0.71	6.12	1.20	17.69	1.19	23.17	1.99	19.63	0.42
Hexanoic acid	55.21	6.97	140.31	2.73	153.11	8.79	165.68	4.19	189.39	10.25
Octanoic acid	148.50	14.59	181.55	15.17	365.02	41.61	168.02	2.73	323.04	28.23
Alcohols										
1-Butanol	6.40	0.56	11.71	1.00	8.24	0.80	5.98	0.08	4.75	0.34
Isoamyl alcohol	1175.00	148.49	744.98	135.32	2134.28	288.03	571.15	0.33	1144.57	77.82
Phenylethyl alcohol	382.37	10.80	342.87	10.10	480.01	42.44	348.44	16.38	257.87	7.93
C_6 alcohols										
1-Hexanol	643.71	75.85	727.70	83.60	522.38	38.76	416.54	0.42	453.39	16.92
cis-3-Hexen-1-ol	4.37	0.61	7.31	0.98	4.59	0.30	4.00	0.05	5.58	0.21
trans-3-Hexen-1-ol	37.61	1.40	37.17	5.59	25.93	1.85	17.11	0.30	19.06	0.83
cis-2-Hexen-1-ol	154.78	0.20	328.87	33.54	48.79	5.85	185.20	2.26	276.08	9.26
Terpenes										
α-Phellandrene	2.08	17.25	4.80	0.93	2.01	0.04	2.72	0.38	3.92	0.33
Limonene	0.22	0.03	0.73	0.12	0.45	0.08	0.56	0.06	1.38	0.03
p-Cymene	1.24	0.19	3.78	0.64	0.31	0.05	0.23	0.03	0.45	0.02
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.00	0.00	0.32	0.45	0.54	0.02	0.61	0.18	0.72	0.07
cis-Linaloloxide	0.27	0.01	0.58	0.04	0.52	0.06	0.40	0.06	0.89	0.02
Linalool	2.40	0.07	5.67	0.11	3.20	0.59	5.24	0.03	5.66	0.44
α-Terpineol	0.44	1.00	0.58	0.93	0.53	#DIV/0!	0.62	0.40	1.78	0.00
β citronellol	4.49	0.45	2.21	0.16	1.23	0.03	1.05	0.17	0.50	0.08
Nerol	0.00		0.00		0.00		0.00		0.00	
Geraniol	4.43	0.18	1.81	0.05	1.87	0.37	3.13	0.29	0.93	0.16
Norisoprenoids										
3-Hydroxy-β-damascone	0.00		0.00		0.00		0.00		0.00	
β-Damascenone	4.23	0.80	4.93	1.00	4.89	0.80	1.32	0.22	5.30	0.41
Vitispirane	0.33	0.13	0.52	0.09	0.75	0.07	0.16	0.03	2.40	0.30
TPB	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.04	0.01
TDN	0.09	0.03	0.16	0.02	0.16	0.01	0.05	0.01	0.40	0.06
Benzenoids										
Benzaldehyde	163.865	12.49458	40.045	8.60549	128.275	20.37175	41.85	6.22254	2.005	0.035355
Methyl salycilate	0.48	0.09	0.53	0.11	0.43	0.08	1.72	0.28	0.31	0.06
Benzyl alcohol	119.39	20.73237	173.135	22.32336	47.875	0.459619	101.89	2.955706	82.58	6.010408
Vanillin	27.87	4.39	20.13	1.59	23.30	1.61	20.62	0.19	22.87	0.97
Ethyl-vanillate	166.78	8.09	205.99	3.92	195.62	18.13	285.13	0.42	73.59	0.66
Eugenol	2.995	0.021213	5.07	0.098995	3.89	0.014142	3.7	0.19799	2.145	0.205061
Bound Compounds										
Alcohols										
1-Butanol	1.41	0.01	1.50	0.07	1.48	0.25	1.29	0.16	1.08	0.12
isoamyl alcohol	16.94	1.58	20.15	0.75	22.04	5.57	24.50	2.17	11.84	1.81
Phenylethyl Alcohol	52.63	2.04	67.63	0.01	79.44	15.89	43.86	2.84	50.41	8.99
C_6 alcohols										
1-Hexanol	42.04	2.30	58.20	0.42	52.56	3.62	49.28	9.94	53.98	10.25
cis-3-Hexen-1-ol	0.29	0.04	0.36	0.04	0.44	0.09	0.41	0.08	0.44	0.04
trans-3-Hexen-1-ol	2.59	0.25	2.63	0.24	2.99	0.45	2.28	0.28	3.32	1.03
cis-2-Hexen-1-ol	4.38	0.23	5.03	0.28	5.03	0.54	4.51	0.26	5.46	0.28
Terpenes										
Limonene	0.19	0.01	0.20	0.01	0.27	0.04	0.31	0.01	0.20	0.03
p-Cymene	0.02	0.00	0.02	0.00	0.05	0.00	0.05	0.00	0.03	0.00
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	0.83	0.04	3.57	0.01	1.90	0.32	4.77	1.34	3.01	0.49
α-Terpineol	0.37	0.03	1.03	0.04	0.52	0.09	1.32	0.97	0.90	0.10
β citronellol	2.29	0.23	1.53	0.05	1.04	0.04	0.91	0.01	0.91	0.16
Nerol	4.90	0.86	5.87	0.13	4.59	0.83	5.33	0.83	6.50	1.29
Geraniol	17.81	2.16	19.29	0.71	16.32	2.98	15.05	2.49	18.48	3.20
Norisoprenoids										
3-Oxo-α-ionol	1.81	0.10	2.55	0.13	1.92	0.29	1.42	0.25	1.77	0.24
3-Hydroxy-β-damascone	0.57	0.06	0.58	0.01	0.57	0.05	0.34	0.06	0.78	0.07
Benzenoids										
Benzaldehyde	1.19	0.20	1.21	0.05	1.40	0.15	1.07	0.05	0.59	0.07
Methyl salycilate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzyl alcohol	30.95	3.85	28.85	0.76	28.53	4.79	19.40	1.97	25.56	5.03
Vanillin	7.44	2.02	5.07	0.28	5.02	0.20	4.98	0.59	5.97	0.23

Appendix 2.3.2.10. Concentration (μg/L) and standard deviation (± μg/L) of free and bound volatile compounds of 2018 withered Corvinone grapes

	Vineyard 1		Vineyard 2		Vineyard 3		Vineyard 4		Vineyard 5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	7.89	1.70	8.35	1.11	9.02	4.16	2.75	0.11	3.42	0.63
Ethyl decanoate	1.06	0.18	5.57	0.59	3.95	2.43	1.36	0.06	1.08	0.11
Fatty acids										
3-Methylbutanoic acid	18.90	3.17	14.44	1.13	19.28	4.93	20.98	4.01	8.48	0.63
Hexanoic acid	97.76	4.68	98.97	0.48	111.39	10.25	78.68	7.08	108.33	2.34
Octanoic acid	126.41	4.89	358.78	13.34	282.16	40.88	175.66	15.58	209.05	8.43
Alcohols										
1-Butanol	7.12	0.25	5.67	0.98	9.40	4.04	2.02	0.18	3.19	0.72
Isoamyl alcohol	699.01	13.93	1256.49	136.83	2796.3	910.27	246.09	30.99	562.15	10.50
Phenylethyl alcohol	245.98	14.88	179.91	6.19	431.31	109.66	95.90	7.15	144.39	5.85
C_6 alcohols										
1-Hexanol	982.16	24.37	565.51	24.17	926.78	252.65	373.04	11.84	763.06	25.58
cis-3-Hexen-1-ol	13.52	0.01	10.66	0.67	21.12	6.19	9.31	0.17	26.22	0.54
trans-3-Hexen-1-ol	25.75	0.25	13.23	1.00	19.91	5.73	11.48	0.79	20.74	0.42
cis-2-Hexen-1-ol	107.02	18.36	396.94	14.62	322.13	73.43	484.38	35.62	926.95	29.39
Terpenes										
α-Phellandrene	17.77	0.21	1.09	0.09	1.04	0.19	0.86	0.01	3.46	0.23
Limonene	0.67	0.03	0.20	0.00	0.20	0.02	0.19	0.03	0.99	0.12
p-Cymene	0.27	0.02	0.16	0.01	0.36	0.06	0.12	0.04	0.25	0.03
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.67	0.12	0.11	0.16	1.18	0.16	0.89	0.12	0.74	0.25
cis-Linaloloxide	0.44	0.07	0.28	0.01	0.47	0.08	0.47	0.10	0.48	0.06
Linalool	3.86	0.55	2.05	0.35	0.98	0.01	1.92	0.09	4.15	0.01
α-Terpineol	0.53	0.98	0.25	0.02	0.23	0.34	0.40	0.93	1.52	0.00
β citronellol	0.82	0.02	0.70	0.01	0.13	0.18	0.27	0.04	0.51	0.15
Nerol	0.00		0.00		0.00		0.00		0.00	
Geraniol	0.70	0.07	0.92	0.04	1.11	0.22	0.77	0.31	0.51	0.07
Norisoprenoids										
3-Hydroxy-β-damascone	0.00		0.00		0.00		0.00		0.00	
β-Damascenone	7.40	0.18	3.43	0.27	2.77	0.52	1.13	0.22	3.21	0.07
Vitispirane	0.72	0.04	0.18	0.08	0.22	0.04	0.18	0.00	1.87	0.37
TPB	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00
TDN	0.11	0.01	0.06	0.01	0.02	0.01	0.03	0.01	0.18	0.02
Benzenoids										
Benzaldehyde	96.21	5.388154	5.775	0.756604	13.945	3.896158	5.04	0.947523	1.875	0.035355
Methyl salycilate	0.62	0.10	0.18	0.01	0.30	0.06	0.23	0.14	0.43	0.08
Benzyl alcohol	14.72	1.909188	39.005	3.075914	17	2.559727	13.28	1.513209	9.98	0.537401
Vanillin	31.71	1.01	16.83	1.20	28.38	7.99	26.95	4.06	24.75	2.24
Ethyl-vanillate	286.17	5.20	126.17	15.50	363.86	57.56	272.52	50.18	133.75	7.71
Eugenol	1.275	0.13435	1.42	0.014142	1.045	0.06364	0.3	0.424264	0.39	0
Bound Compounds										
Alcohols										
1-Butanol	2.04	0.35	2.49	0.11	3.71	0.50	4.33	0.37	1.42	0.17
isoamyl alcohol	26.58	2.21	10.25	0.78	38.64	6.45	25.04	3.46	18.67	1.24
Phenylethyl Alcohol	80.80	4.79	106.34	8.44	80.73	2.97	63.09	0.96	52.02	2.20
C_6 alcohols										
1-Hexanol	107.21	5.21	140.07	10.77	134.73	8.05	107.98	1.73	76.58	0.09
cis-3-Hexen-1-ol	0.90	0.03	1.18	0.04	1.14	0.16	0.84	0.05	1.01	0.04
trans-3-Hexen-1-ol	5.37	0.35	5.20	0.43	4.27	0.14	4.11	0.19	3.12	0.17
cis-2-Hexen-1-ol	17.82	0.93	24.03	0.82	18.76	2.31	17.65	0.30	16.61	0.77
Terpenes										
Limonene	0.11	0.01	0.14	0.01	0.43	0.04	0.13	0.01	0.14	0.02
p-Cymene	0.02	0.00	0.03	0.00	0.06	0.01	0.07	0.01	0.05	0.00
Terpinolene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	2.75	0.47	1.13	0.04	1.07	0.14	1.66	0.08	2.79	0.06
α-Terpineol	0.27	0.02	0.23	0.03	0.20	0.01	0.19	0.03	0.43	0.02
β citronellol	1.20	0.07	1.06	0.11	0.94	0.04	2.89	0.17	0.84	0.13
Nerol	11.55	1.02	14.54	1.38	10.73	0.42	17.82	0.42	10.18	0.25
Geraniol	40.21	5.89	49.22	1.75	39.53	3.41	49.02	0.57	37.64	5.13
Norisoprenoids										
3-Oxo-α-ionol	2.72	0.37	4.18	0.11	2.91	0.49	3.13	0.03	2.13	0.15
3-Hydroxy-β-damascone	0.88	0.06	1.24	0.18	0.71	0.11	0.64	0.01	0.76	0.13
Benzenoids										
Benzaldehyde	1.33	0.16	0.95	0.07	0.90	0.13	0.96	0.03	0.59	0.09
Methyl salycilate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzyl alcohol	31.02	0.67	33.61	3.12	22.74	0.86	27.35	0.33	22.06	0.47
Vanillin	6.02	0.54	7.19	0.97	5.70	0.63	5.29	0.38	4.87	0.19

Appendix 2.3.2.11. Concentration (µg/L) and standard deviation (± µg/L) of free and bound volatile compounds of 2019 withered Corvina grapes										
	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	19.98	1.09	6.38	0.04	8.13	0.16	5.87	0.01	13.51	0.59
Ethyl decanoate	0.89	0.04	0.88	0.03	1.07	0.01	0.72	0.03	1.11	0.07
Fatty acids										
3-Methylbutanoic acid	28.12	1.36	8.44	0.27	27.63	0.57	1.34	0.02	13.79	0.36
Hexanoic acid	239.38	1.52	208.24	7.32	212.60	7.08	168.95	5.37	253.26	5.45
Octanoic acid	156.46	1.78	156.48	4.29	184.74	4.87	107.68	3.51	241.99	0.17
Alcohols										
1-Butanol	12.08	0.19	6.27	0.14	9.92	0.51	1.88	0.08	10.71	0.36
Isoamyl alcohol	984.39	37.92	1121.05	11.18	2097.09	31.47	179.52	1.89	3012.54	51.75
Phenylethyl alcohol	395.51	1.95	232.37	5.51	398.87	4.48	57.64	0.77	549.03	17.06
C_6 alcohols										
1-Hexanol	335.17	14.91	350.09	0.74	412.41	21.35	167.13	6.18	438.79	7.06
cis-3-Hexen-1-ol	3.10	0.11	4.30	0.05	3.40	0.04	2.49	0.01	3.71	0.09
trans-3-Hexen-1-ol	21.28	0.84	18.49	0.37	12.78	0.41	6.55	0.36	13.32	0.03
cis-2-Hexen-1-ol	13.89	0.16	67.28	3.17	120.07	2.51	42.91	2.23	6.90	0.08
Terpenes										
α-Phellandrene	4.42	0.21	5.85	0.37	2.38	2.81	0.96	0.83	5.89	1.00
Limonene	1.26	0.13	1.15	1.38	2.77	0.11	0.72	0.01	2.84	1.00
p-Cymene	16.00	0.97	0.79	0.12	0.87	0.04	1.43	0.09	0.75	0.30
Terpinolene	0.46	0.03	1.11	0.24	1.26	0.00	0.36	0.01	1.37	0.44
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	1.13	0.01	0.92	0.05	1.44	0.04	0.56	0.01	2.34	0.06
Linalool	1.51	0.18	9.27	0.52	7.37	0.41	3.58	0.16	14.18	4.89
α-Terpineol	0.83	0.13	3.31	0.23	2.16	0.57	1.11	0.12	5.06	0.72
β citronellol	2.84	1.67	2.98	0.09	2.56	2.02	1.34	0.25	2.02	0.83
Nerol	0.30	0.01	0.69	0.01	0.97	0.05	0.21	0.01	1.35	0.07
Geraniol	10.29	0.41	9.86	2.41	14.25	2.35	4.96	0.29	7.15	0.30
Norisoprenoids										
3-Hydroxy-β-damascone	0.10	0.00	0.03	0.00	0.10	0.00	0.10	0.00	0.20	0.00
β-Damascenone	1.66	0.02	4.90	0.49	4.80	0.05	3.95	0.05	5.66	0.52
Vitispirane	0.40	0.02	0.42	0.01	1.03	0.04	0.35	0.00	1.62	0.14
TPB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TDN	0.10	0.00	0.29	0.00	0.30	0.01	0.13	0.00	0.39	0.14
Benzenoids										
Benzaldehyde	67.05	0.33	7.09	0.03	7.61	0.45	14.82	0.56	10.27	0.13
Methyl salycilate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzyl alcohol	82.78	2.57	99.05	5.01	46.31	2.25	74.29	1.14	42.79	2.36
Vanillin	33.46	0.19	22.13	0.13	27.17	0.43	25.91	0.69	29.52	1.37
Ethyl-vanillate	185.93	8.55	40.81	0.63	63.60	2.96	46.97	2.73	88.93	4.83
Eugenol	1.75	0.08	3.49	0.10	1.75	0.03	2.18	0.03	1.94	0.03
Bound Compounds										
Alcohols										
1-Butanol	2.67	0.02	1.90	0.01	1.39	0.02	1.45	0.00	0.83	0.01
isoamyl alcohol	42.87	0.71	27.53	0.80	34.73	1.62	19.04	0.54	36.86	1.79
Phenylethyl Alcohol	109.13	0.39	25.80	0.86	29.58	1.09	18.58	0.97	38.41	1.25
C_6 alcohols										
1-Hexanol	45.88	1.86	22.18	1.02	25.60	1.33	19.43	0.84	27.19	0.68
cis-3-Hexen-1-ol	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
trans-3-Hexen-1-ol	3.50	0.16	1.45	0.00	1.62	0.07	0.92	0.04	1.49	0.09
cis-2-Hexen-1-ol	14.87	0.06	13.54	0.23	13.37	0.34	14.35	0.51	13.45	0.51
Terpenes										
Limonene	0.48	0.01	0.23	0.01	0.19	0.01	0.32	0.01	0.21	0.01
p-Cymene	0.18	0.00	0.11	0.00	0.10	0.00	0.11	0.00	0.10	0.00
Terpinolene										
trans-Linaloloxide	1.15	0.06	0.37	0.02	0.30	0.02	0.00	0.00	0.42	0.02
cis-Linaloloxide	0.94	0.04	0.45	0.00	0.29	0.01	0.00	0.00	0.38	0.01
Linalool	2.42	0.02	6.26	0.24	2.14	0.09	2.85	0.02	4.23	0.19
α-Terpineol	0.63	0.03	1.38	0.00	0.70	0.03	0.47	0.02	0.98	0.02
β citronellol	4.08	0.09	2.38	0.02	1.87	0.07	1.62	0.09	2.79	0.08
Nerol	3.99	0.20	4.83	0.20	4.51	0.03	5.27	0.26	4.77	0.15
Geraniol	16.64	0.43	13.58	0.59	12.24	0.33	11.25	0.20	13.99	0.81
Norisoprenoids										
3-Oxo-α-ionol	0.30	0.00	0.58	0.03	0.45	0.02	0.24	0.01	0.21	0.00
3-Hydroxy-β-damascone	0.38	0.02	0.15	0.00	0.15	0.00	0.17	0.01	0.17	0.00
Benzenoids										
Benzaldehyde	1.17	0.00	0.41	0.01	0.54	0.03	0.49	0.02	0.59	0.02
Methyl salycilate										
Benzyl alcohol	43.96	0.31	19.22	0.60	14.40	0.21	22.09	0.59	10.67	0.23
Vanillin	9.44	0.21	4.15	0.05	4.87	0.04	4.75	0.23	3.51	0.19
Methyl-vanillate	74.34	2.47	21.66	0.23	26.75	0.06	21.30	0.43	25.47	0.05

Appendix 2.3.2.12. Concentration (µg/L) and standard deviation (± µg/L) of free and bound volatile compounds of 2019 withered Corvinone grapes										
	Vineyard 1		**Vineyard 2**		**Vineyard 3**		**Vineyard 4**		**Vineyard 5**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Free Compounds										
Fatty acid ethyl esters										
Ethyl hexanoate	5.43	0.03	4.14	0.18	7.50	0.38	3.85	0.05	9.61	0.31
Ethyl decanoate	0.51	0.03	0.00	0.00	0.85	0.04	0.53	0.03	1.08	0.04
Fatty acids										
3-Methylbutanoic acid	173.04	6.43	3.51	0.10	10.03	0.09	0.53	0.01	39.34	1.88
Hexanoic acid	88.99	3.29	147.31	7.04	156.76	1.21	138.39	0.10	221.57	2.79
Octanoic acid	153.00	7.15	128.52	2.24	148.44	6.94	116.67	2.09	249.18	9.59
Alcohols										
1-Butanol	4.15	0.21	0.12	0.00	1.52	0.08	2.88	0.09	2.81	0.01
Isoamyl alcohol	1105.62	48.48	51.11	2.00	201.04	3.31	153.21	0.00	1096.73	20.66
Phenylethyl alcohol	194.33	6.33	48.98	0.03	50.30	0.75	31.58	1.07	308.48	15.35
C_6 alcohols										
1-Hexanol	501.64	23.00	475.33	23.66	566.86	30.46	211.00	10.66	515.29	19.45
cis-3-Hexen-1-ol	6.90	0.19	8.77	0.40	10.25	0.15	4.42	0.12	7.05	0.04
trans-3-Hexen-1-ol	7.73	0.06	6.17	0.10	8.09	0.12	6.05	0.16	7.28	0.29
cis-2-Hexen-1-ol	139.03	3.50	193.78	0.68	224.98	1.60	60.12	1.50	176.83	1.00
Terpenes										
α-Phellandrene	1.16	0.32	0.76	0.37	1.85	2.02	2.48	0.08	3.16	0.13
Limonene	6.62	0.66	2.89	1.05	1.40	0.01	1.04	0.25	1.80	0.05
p-Cymene	15.57	2.45	0.63	0.07	0.42	0.01	0.37	0.13	0.46	0.02
Terpinolene	0.09	0.01	0.70	0.37	0.73	0.15	0.34	0.31	0.79	0.07
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.83	0.04	0.00	0.00	0.30	0.01	0.38	0.01	0.50	0.02
Linalool	3.75	0.83	6.19	1.60	6.96	0.21	6.32	1.39	6.30	1.82
α-Terpineol	2.44	0.11	2.42	0.45	2.32	0.00	2.21	1.16	2.65	0.15
β citronellol	2.36	0.81	1.23	0.24	0.99	0.30	1.02	0.12	2.38	0.67
Nerol	12.45	1.78	4.08	0.11	4.17	0.91	4.65	0.47	1.56	0.08
Geraniol	17.94	0.11	9.72	1.84	7.24	1.13	5.55	2.65	11.05	0.79
Norisoprenoids										
3-Hydroxy-β-damascone	0.09	0.00	0.07	0.00	0.11	0.00	0.07	0.00	0.08	0.00
β-Damascenone	3.43	0.57	4.83	0.54	7.30	0.09	3.76	0.92	5.54	0.33
Vitispirane	2.56	0.41	1.58	0.04	0.99	0.04	0.79	0.08	3.43	0.34
TPB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TDN	0.43	0.09	0.24	0.01	0.21	0.03	0.13	0.01	0.40	0.03
Benzenoids										
Benzaldehyde	4.96	0.07	3.33	0.12	5.18	0.04	6.16	0.03	5.15	0.17
Methyl salycilate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Benzyl alcohol	19.45	0.40	14.78	0.78	15.16	0.35	26.47	0.61	11.32	0.45
Vanillin	23.08	1.18	17.01	0.13	22.33	1.11	24.76	0.74	26.14	0.29
Ethyl-vanillate	98.18	5.21	46.38	1.96	57.13	2.50	55.82	1.78	83.27	4.59
Eugenol	0.73	0.01	0.89	0.02	0.00	0.00	1.15	0.06	0.47	0.02
Bound Compounds										
Alcohols										
1-Butanol	1.78	0.05	2.21	0.10	2.26	0.11	1.52	0.01	2.91	0.04
isoamyl alcohol	51.06	1.06	20.03	0.85	23.70	0.41	15.59	0.58	61.49	0.83
Phenylethyl Alcohol	40.46	0.00	23.64	0.17	32.91	0.98	23.54	0.67	62.01	0.98
C_6 alcohols										
1-Hexanol	47.16	1.02	42.45	1.26	37.64	1.77	23.52	0.87	47.28	1.57
cis-3-Hexen-1-ol	0.52	0.02	0.48	0.01	0.46	0.00	0.25	0.00	0.51	0.03
trans-3-Hexen-1-ol	1.61	0.09	1.47	0.01	1.94	0.00	1.22	0.02	2.55	0.05
cis-2-Hexen-1-ol	14.39	0.73	13.71	0.27	14.17	0.44	13.75	0.07	13.84	0.19
Terpenes										
Limonene	0.27	0.01	0.24	0.00	0.26	0.00	0.25	0.00	0.22	0.00
p-Cymene	0.09	0.00	0.11	0.00	0.12	0.01	0.11	0.00	0.09	0.00
Terpinolene										
trans-Linaloloxide	0.38	0.01	0.00	0.00	0.24	0.01	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.42	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	2.21	0.08	2.70	0.09	4.51	0.23	2.99	0.11	3.32	0.03
α-Terpineol	0.87	0.01	0.56	0.03	0.38	0.01	0.46	0.02	0.72	0.03
β citronellol	2.09	0.01	2.09	0.06	2.26	0.02	1.48	0.01	4.11	0.22
Nerol	5.15	0.26	9.92	0.58	7.87	0.36	4.52	0.11	8.57	0.16
Geraniol	17.92	0.73	38.09	0.53	34.19	1.70	13.51	0.58	25.24	0.78
Norisoprenoids										
3-Oxo-α-ionol	0.45	0.01	0.25	0.00	0.26	0.01	0.15	0.00	0.35	0.02
3-Hydroxy-β-damascone	0.22	0.00	0.26	0.01	0.31	0.01	0.18	0.00	0.31	0.01
Benzenoids										
Benzaldehyde	0.55	0.03	0.46	0.02	0.45	0.03	0.56	0.02	0.51	0.00
Methyl salycilate										
Benzyl alcohol	10.77	0.00	13.99	0.49	14.78	0.01	20.15	0.63	1.08	0.01
Vanillin	5.14	0.05	5.22	0.02	4.84	0.16	4.46	0.23	3.05	0.00
Methyl-vanillate	54.67	2.03	27.97	0.28	31.88	1.78	23.36	0.84	39.11	1.24

Appendix 2.3.2.13. Significantly different compounds between fresh and withered grapes according to Mann-Whitney test (α=0.05)

	Corvina	**Corvinone**
Ethyl hexanoate	0.476	0.328
Ethyl decanoate	0.077	0.164
3-Methylbutanoic acid	**<0.0001**	**<0.0001**
Hexanoic acid	0.068	**<0.0001**
Octanoic acid	0.350	**0.011**
1-Butanol	**<0.0001**	**<0.0001**
Isoamyl alcohol	**<0.0001**	**<0.0001**
Phenylethyl Alcohol	**<0.0001**	**0.000**
1-Hexanol	**0.004**	**<0.0001**
trans-3-Hexen-1-ol	**<0.0001**	**<0.0001**
cis-3-Hexen-1-ol	**<0.0001**	**<0.0001**
cis-2-Hexen-1-ol	**<0.0001**	**<0.0001**
alpha-phellandrene	**<0.0001**	**<0.0001**
limonene	**0.001**	**0.000**
p-cymene	**<0.0001**	**<0.0001**
Terpinolene	0.706	0.517
trans-Linaloloxide	0.110	0.950
cis-Linaloloxide	**<0.0001**	**<0.0001**
Linalol	0.756	**<0.0001**
alpha-Terpineol	0.152	0.162
beta citronellol	**<0.0001**	**<0.0001**
Nerol	0.477	**<0.0001**
Geraniol	1.000	**<0.0001**
3-hydroxy-beta-damascone	**0.006**	**0.031**
beta-damascenone	**<0.0001**	**<0.0001**
vitispirane	0.158	0.117
TPB	**0.000**	**<0.0001**
TDN	0.135	**0.031**
Benzaldehyde	**<0.0001**	**0.000**
methyl salycilate	**0.000**	**<0.0001**
Benzyl Alcohol	**0.000**	**<0.0001**
Vanillin	**0.000**	**0.001**
Ethyl-vanillate	0.053	0.947
eugenol	**0.008**	**0.001**
Buond 1-Butanol	0.145	0.739
Buond isoamyl alcohol	**<0.0001**	**<0.0001**
Buond Phenylethyl Alcohol	**0.001**	**<0.0001**
Buond 1-Hexanol	**<0.0001**	**<0.0001**
Buond trans-3-Hexen-1-ol	**0.002**	**0.008**
Buond cis-3-Hexen-1-ol	**0.036**	0.243
Buond cis-2-Hexen-1-ol	**<0.0001**	**<0.0001**
Buond Limonene	**<0.0001**	**<0.0001**
Buond p-cymene	**0.021**	**0.023**
Buond trans-Linaloloxide	0.120	**0.008**
Buond cis-Linaloloxide	0.080	**0.004**
Buond Linalol	**<0.0001**	**0.008**
Buond alpha-Terpineol	0.745	**0.000**
Buond beta citronellol	0.882	**0.002**
Buond Nerol	**<0.0001**	0.848
Buond Geraniol	**0.039**	**<0.0001**
Buond 3-oxo-alpha-ionol	**0.000**	**<0.0001**
Buond 3-hydroxy-beta-damascone	**0.006**	0.191
Buond Benzaldehyde	**0.006**	**0.023**
Buond Methyl-salycilate	**<0.0001**	**<0.0001**
Buond Benzyl Alcohol	**0.011**	**0.009**

Appendix 3.3.1.1. Enological parameters of Corvina and Corvinone fresh grapes musts at crush

	PAN[a] (mg/L)		AMMONIA (mg/L)		YAN[b] (mg/L)		Glucose + fructose (g/L)		pH	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Area 1 Corvina	92.1 b	7.3	56.1 b	7.5	138.2 b	12.9	199.6 ab	4.1	3.13 ab	0.03
Area 2 Corvina	84.7 a	3.8	48.8 a	3.7	124.8 a	6.5	203.1 ab	9.4	3.1 a	0.05
Area 1 Corvinone	117.2 d	6.7	77.2 d	6.1	180.7 d	11.4	192.5 a	12.9	3.17 b	0.03
Area 2 Corvinone	103.6 c	5.9	66.7 c	5.8	158.5 c	10.2	207.7 b	7.5	3.18 b	0.03

[a] PAN: Primary Amino Nitrogen; [b]YAN: Yeast Assimilable Nitrogen. Different letters denote statistically significant difference as obtained by ANOVA (α=0.05) with post-hoc Tukey test

Appendix 3.3.1.2. Enological parameters of fresh grapes wines at the end of alcoholic fermentation.

		Yeast 1		Yeast 2		Yeast 3		Yeast 4		Spontaneous	
		mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Area 1 Corvina	Total acidity (g/L)	6.1	0.1	8.0	0	6.5	0.1	5.9	0	7.6	0.1
	pH	3.05	0.01	2.96	0.01	3.05	0.01	3.01	0.01	2.99	0.03
	Acetic acid (g/L)	0.16	0.1	0.32	0	0.28	0.1	0.12	0	0.20	0
	Ethanol (% v/v)	11.94	0.06	12.01	0.04	11.96	0.21	12.02	0.06	11.96	0.11
Area 2 Corvina	Total acidity (g/L)	6.5	0.2	8.3	0.1	7.6	0.1	7.1	0.1	8.3	0.1
	pH	2.88	0.01	2.92	0.03	2.83	0.04	2.91	0.01	2.78	0
	Acetic acid (g/L)	0.16	0	0.24	0.1	0.26	0.1	0.14	0	0.18	0
	Ethanol (% v/v)	11.74	0.006	12.01	0.04	11.87	0.05	11.93	0.16	11.94	0.04
Area 1 Corvinone	Total acidity (g/L)	6.7	0.1	7.7	0.2	5.8	0.1	6.1	0.1	7.3	0.1
	pH	3.12	0.02	3.03	0.04	3.14	0.01	3.06	0.01	3.05	0.04
	Acetic acid (g/L)	0.27	0.1	0.22	0.1	0.16	0	0.14	0	0.26	0.1
	Ethanol (% v/v)	11.95	0.06	12.03	0.03	11.97	0.25	12.09	0.13	11.96	0.13
Area 2 Corvinone	Total acidity (g/L)	6.4	0.1	9.0	0	6.8	0.1	6.5	0.1	7.4	0.1
	pH	2.95	0.07	2.91	0.01	2.97	0.03	3.01	0	2.9	0.01
	Acetic acid (g/L)	0.20	0	0.18	0	0.22	0	0.12	0	0.18	0
	Ethanol (% v/v)	12.06	0.06	12.83	0.06	11.72	0.06	12.48	0.04	11.97	0.08

Appendix 3.3.1.3. One-way and two-way ANOVA analysis (α=0.05) of enological parameters of fresh grapes wines at the end of alcoholic fermentation.

	Corvina						Corvinone					
	Area		Yeast		Area*Yeast		Area		Yeast		Area*Yeast	
	Pr > F	*S*[a]	*Pr > F*	*S*[a]	*Pr > F*	*S*[a]	*Pr > F*	*S*[a]	*Pr > F*	*S*[a]	*Pr > F*	*S*[a]
Total acidity	0.06	Yes	0.00	Yes	<0,0001	Yes	0.19	No	<0,0001	Yes	0.00	Yes
pH	< 0.001	Yes	0.80	No	<0,0001	Yes	0.03	Yes	0.08	No	< 0.001	Yes
Acetic acid	0.60	No	0.00	Yes	0.08	No	0.33	No	0.11	No	0.68	No
Ethanol	0.00	Yes	0.97	No	0.07	No	0.03	Yes	0.75	No	0.79	No

[a]: Significance according to ANOVA analysis.

Appendix 3.3.1.4. Concentration (μg/L) and standard deviation (± μg/L) of volatile compounds of Area 1 Corvina fresh grapes wines

	Yeast 1		Yeast 2		Yeast 3		Yeast 4		Spontaneous	
Alcohols	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1-Butanol	122.35	18.89	30.96	4.21	96.31	14.88	79.65	3.44	95.34	15.92
2-Butanol	4754.15	516.08	5066.65	785.21	7436.22	591.31	3367.31	443.36	6183.53	900.13
1-Pentanol	54.19	2.23	65.98	4.52	53.63	2.98	58.06	2.44	50.14	2.54
Isoamyl alcohol	200766.9 0	41624.6 9	127612.4 4	18663.9 5	207312. 00	35683.44	128934.53	6645.9 9	165303.5 4	18030.17
Phenethyl Alcohol	17843.47	3650.70	8463.27	1437.53	16316.0 5	3379.22	10618.33	40.72	12538.69	864.87
Methionol	568.05	48.40	196.93	39.48	442.90	65.83	592.42	61.45	236.33	49.74
C_6 alcohols										
1-Hexanol	1908.95	13.36	1999.98	288.02	1871.12	79.62	1823.62	56.01	1964.68	183.38
trans-3-Hexen-1-ol	24.99	0.66	27.69	3.67	24.80	0.16	23.01	0.94	15.24	2.03
cis-3-Hexen-1-ol	342.05	16.83	316.73	7.66	381.92	33.31	359.59	17.05	334.87	58.53
cis-2-Hexen-1-ol	13.53	0.16	12.74	0.51	13.14	0.23	12.99	0.52	12.85	0.11
Acetate esters										
Isoamyl acetate	689.11	20.22	776.42	112.93	592.05	87.98	375.62	139.13	569.68	70.32
n-Hexyl acetate	10.18	0.18	8.36	0.45	5.13	0.33	7.17	2.31	6.61	0.40
2-Phenethyl acetate	31.85	0.34	22.80	2.32	22.62	0.78	20.79	0.95	28.15	3.90
Ethyl acetate	37166.75	4901.37	61875.72	8240.78	38044.5 5	9050.34	26928.97	8510.6 4	79875.61	13114.12
Branched-chain fatty acids ethyl esters										
Ethyl 2-methyl butanoate	1.98	0.01	2.85	0.12	2.93	0.23	2.02	0.09	2.36	0.27
Ethyl 3-methyl butanoate	1.17	0.10	3.49	0.33	4.82	0.14	1.43	0.07	2.75	0.11
Fatty acids ethyl esters										
Ethyl butanoate	165.57	14.18	227.62	42.04	149.66	32.86	147.63	31.64	146.45	7.12
Ethyl hexanoate	591.46	1.31	643.46	101.14	617.57	173.01	493.77	116.29	511.05	82.22
Ethyl octanoate	345.22	6.14	373.28	58.29	395.62	72.66	257.28	70.38	258.71	46.95
Ethyl decanoate	78.80	4.62	77.55	5.59	88.73	23.49	65.04	21.06	50.91	6.13
Other esters										
Ethyl 3-hydroxybutanoate	256.18	30.84	267.01	32.01	386.95	30.61	163.26	17.25	273.50	24.20
Ethyl 2-hydroxyhexanoate	0.38	0.03	1.01	0.14	1.36	0.10	0.39	0.01	1.02	0.07
Fatty acids										
3-Methylbutanoic acid	408.47	52.87	432.76	55.32	486.09	48.02	364.98	0.82	289.17	31.23
Hexanoic acid	4032.16	452.00	4942.90	813.38	3906.8	697.68	3189.58	569.6	3531.62	590.9
Octanoic acid	6361.54	391.43	6512.38	1130.3	6070.5	774.51	5393.54	498.3	5273.32	526.5
Terpenoids										
cis-Linalooloxide	0.17	0.02	0.50	0.00	0.24	0.00	0.35	0.04	0.57	0.04
trans-Linalooloxide	0.46	0.00	0.53	0.04	0.48	0.03	0.56	0.01	0.51	0.08
Linalool	6.12	0.47	6.56	0.74	8.12	1.24	6.96	0.11	7.07	0.54
Geraniol	4.75	0.72	5.04	0.03	7.43	0.13	14.62	2.55	4.51	0.05
β-Citronellol	15.52	1.73	13.04	1.40	13.36	0.30	11.34	0.55	15.35	1.22
α-Terpineol	1.53	0.04	2.04	0.28	2.24	0.23	1.56	0.13	2.22	0.13
α-Phellandrene	2.56	0.30	2.72	0.23	3.37	0.42	3.53	0.16	2.68	0.23
α-Terpinen	0.05	0.01	0.06	0.00	0.06	0.00	0.07	0.00	0.07	0.01
β-Myrcene	2.84	0.37	3.55	0.03	4.38	0.54	5.23	0.55	3.48	0.30
Limonene	0.29	0.03	0.32	0.04	0.43	0.02	0.46	0.08	0.37	0.04
1,8-Cineol	0.08	0.01	0.00	0.00	0.06	0.00	0.07	0.01	0.06	0.01
p-Cymene	0.15	0.02	0.18	0.01	0.15	0.00	0.16	0.01	0.16	0.01
Terpinolene	0.19	0.02	0.21	0.01	0.28	0.02	0.33	0.04	0.26	0.03
Terpinen-1-ol	0.17	0.01	0.16	0.01	0.14	0.01	0.15	0.02	0.13	0.01
Terpinen-4-ol	0.00	0.00	0.00	0.00	0.15	0.02	0.20	0.02	0.15	0.01
Nerol	1.20	0.08	1.23	0.09	1.07	0.08	0.97	0.01	0.97	0.02
Norisoprenoids										
β-Damascenone	1.39	0.07	1.54	0.02	1.82	0.24	1.73	0.08	1.42	0.11
3-Oxo-α-ionol	1.29	0.20	1.19	0.04	1.17	0.04	1.49	0.01	1.64	0.09
3-Hydroxy-β-damascone	0.12	0.01	0.08	0.00	0.13	0.00	0.12	0.01	0.10	0.01
Vitispirane	0.11	0.01	0.30	0.00	0.24	0.01	0.23	0.01	0.24	0.01
TPB	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
TDN	0.07	0.00	0.09	0.01	0.08	0.01	0.07	0.00	0.08	0.01
Benzenoids and others										
Benzyl Alcohol	139.11	7.96	98.13	10.53	146.93	11.10	150.57	16.30	167.28	10.50
Vanillin	6.00	0.47	4.63	0.15	4.64	0.45	4.78	0.21	3.75	0.08
Vanillyl alcohol	4.40	3.51	9.89m	1.43	6.25	3.83	4.94	0.58	7.41	0.54
Ethyl vanillate	93.62	12.08	119.86	18.16	93.41	9.06	99.93	5.56	100.78	1.36
Methyl vanillate	6.04	0.25	10.18	1.50	6.08	0.17	6.01	0.66	6.78	0.16
Benzaldehyde	14.44	0.22	14.21	0.21	14.56	0.13	14.51	0.06	14.49	0.06
Eugenol	5.95	0.03	4.03	0.57	5.67	0.08	5.90	0.51	5.79	0.45
Methyl salycilate	0.45	0.01	0.56	0.06	0.46	0.06	0.49	0.08	0.48	0.06
2,6-Dimethoxyphenol	9.58	1.38	7.79	0.81	10.02	0.73	8.07	0.16	9.38	1.71
Furfural	1.84	0.06	1.86	0.18	2.24	0.10	0.94	0.64	0.48	0.01
γ-Decalactone	3.12	0.00	2.37	0.06	2.94	0.21	2.65	0.52	3.44	0.40
δ-Decalactone	17.45	1.85	18.75	1.93	16.83	2.71	16.95	1.56	14.72	1.92

Appendix 3.3.1.5. Concentration and standard deviation (μg/L) of volatile compounds of Area 2 Corvina fresh grapes wines.

	Yeast 1		Yeast 2		Yeast 3		Yeast 4		Spontaneous	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	129.27	3.54	86.60	1.80	79.28	3.44	82.03	6.55	79.12	8.50
2-Butanol	4710.82	185.98	5267.86	1041.31	6645.56	346.46	3773.92	214.89	6147.55	2.17
1-Pentanol	48.14	2.04	47.04	5.08	42.66	1.31	48.29	0.10	41.97	1.57
Isoamyl alcohol	199191,56	3845,83	191812,01	6408,83	195398,99	11683,16	153611,39	1270,93	178727,20	6756,43
Phenethyl alcohol	17622.72	297.71	13270.72	358.63	14853.93	266.58	12553.71	162.08	13314.45	43.07
Methionol	423.47	10.47	268.10	45.16	257.37	19.83	544.67	58.83	251.46	7.93
C_6 alcohols										
1-Hexanol	2456.77	84.71	2174.94	46.34	2429.56	239.06	2318.01	41.12	2534.44	241.43
trans-3-Hexen-1-ol	18.06	1.89	16.14	0.74	18.02	2.42	19.10	0.57	12.79	1.64
cis-3-Hexen-1-ol	240.69	10.54	256.92	38.19	292.78	10.30	238.84	13.80	220.40	35.12
cis-2-Hexen-1-ol	15.23	0.00	13.29	0.42	13.66	0.52	13.27	0.44	13.48	0.45
Acetate esters										
Isoamyl acetate	543.38	71.59	1564.80	96.36	761.32	26.33	393.45	9.62	731.98	35.77
n-Hexyl acetate	10.36	0.23	30.48	0.37	10.87	0.96	10.18	0.21	13.37	0.25
2-Phenethyl acetate	36.46	3.05	42.02	1.48	31.87	0.11	24.64	1.91	49.46	0.56
Ethyl acetate	33001.87	862.65	49384.07	2097.55	38248.41	1886.17	24175.72	265.69	76531.61	138.71
Branched-chain fatty acids ethyl esters										
Ethyl 2-methyl butanoate	3.10	0.37	3.70	0.04	4.47	0.16	3.03	0.28	2.39	0.12
Ethyl 3-methyl butanoate	2.91	0.08	6.46	0.54	6.52	0.81	2.16	0.17	2.28	0.18
Fatty acids ethyl esters										
Ethyl butanoate	130.86	7.23	245.09	35.56	113.79	0.76	126.83	6.82	131.91	14.96
Ethyl hexanoate	488.08	39.79	931.03	81.33	454.02	53.79	439.14	18.87	509.42	57.62
Ethyl octanoate	241.98	37.13	426.33	26.90	200.43	54.15	163.07	43.46	206.46	34.39
Ethyl decanoate	43.08	6.93	80.22	3.13	43.34	6.68	34.61	7.85	37.69	6.36
Other esters										
Ethyl 3-hydroxybutanoate	230.32	11.53	248.23	14.96	264.29	19.76	160.48	4.94	249.89	11.29
Ethyl 2-hydroxyhexanoate	0.63	0.10	1.27	0.23	1.92	0.01	0.55	0.04	0.76	0.01
Fatty acids										
3-Methylbutanoic acid	452.51	73.32	486.57	23.85	574.64	10.46	427.19	14.04	283.83	8.78
Hexanoic acid	3167.93	159.97	4523.44	737.75	2829.67	278.07	2713.65	108.76	3114.00	177.93
Octanoic acid	5303.09	10.22	6587.47	352.25	4587.83	401.25	4564.29	6.55	4832.87	383.63
Terpenoids										
cis-Linalooloxide	0.57	0.04	0.39	0.06	0.56	0.06	0.47	0.04	0.70	0.05
trans-Linalooloxide	0.56	0.03	0.69	0.06	0.53	0.03	0.67	0.01	0.71	0.03
Linalool	12.11	0.65	13.76	0.15	12.49	1.01	13.35	0.74	13.91	0.74
Geraniol	3.49	0.36	7.16	0.07	4.94	0.04	7.60	0.81	6.61	0.57
β-Citronellol	10.71	0.06	9.47	0.96	10.47	0.74	8.35	0.08	12.02	0.16
α-Terpineol	3.29	0.19	4.03	0.03	4.06	0.25	3.75	0.25	3.92	0.44
α-Phellandrene	5.12	0.75	5.96	0.16	5.95	0.72	7.20	1.02	5.19	0.02
α-Terpinen	0.11	0.02	0.13	0.01	0.12	0.01	0.16	0.01	0.16	0.01
β-Myrcene	6.65	0.98	7.74	0.22	7.73	0.93	9.35	1.33	6.74	0.02
Limonene	1.06	0.10	1.17	0.14	1.12	0.25	1.49	0.13	1.26	0.01
1,8-Cineol	0.10	0.01	0.12	0.01	0.12	0.02	0.19	0.02	0.13	0.02
p-Cymene	0.20	0.01	0.24	0.02	0.23	0.01	0.22	0.04	0.25	0.04
Terpinolene	0.56	0.07	0.73	0.03	0.64	0.04	0.68	0.06	0.80	0.01
Terpinen-1-ol	0.12	0.01	0.13	0.01	0.12	0.01	0.09	0.04	0.12	0.01
Terpinen-4-ol	0.21	0.02	0.23	0.01	0.44	0.06	0.54	0.19	0.59	0.09
Nerol	0.82	0.16	1.12	0.13	0.52	0.06	0.65	0.06	0.63	0.04
Norisoprenoids										
β-Damascenone	1.92	0.11	1.29	0.09	1.60	0.23	1.78	0.27	1.56	0.06
3-Oxo-α-ionol	0.91	0.01	1.05	0.00	0.85	0.12	0.96	0.03	1.10	0.16
3-Hydroxy-β-damascone	0.18	0.01	0.07	0.00	0.08	0.00	0.07	0.01	0.08	0.01
Vitispirane	1.20	0.04	1.24	0.25	1.74	0.13	1.68	0.12	2.17	0.05
TPB	0.02	0.00	0.02	0.00	0.03	0.00	0.03	0.01	0.04	0.01
TDN	0.31	0.04	0.30	0.02	0.41	0.03	0.36	0.01	0.49	0.00
Benzenoids and others										
Benzyl Alcohol	104.56	16.83	104.99	4.09	101.86	0.45	113.40	5.51	108.87	5.61
Vanillin	4.63	0.42	3.79	0.60	3.67	0.28	4.07	0.08	3.66	0.12
Vanillyl alcohol	4.98	0.95	3.22	2.66	4.61	0.17	4.82	0.80	5.73	0.81
Ethyl vanillate	96.43	1.82	95.34	0.71	91.83	0.77	92.87	2.24	92.95	7.93
Methyl vanillate	8.46	0.78	7.90	0.11	7.94	0.23	7.96	0.39	8.00	0.15
Benzaldehyde	16.57	2.72	14.77	0.05	17.22	0.38	14.73	0.34	14.70	0.12
Eugenol	0.92	0.02	1.21	0.01	0.97	0.06	1.16	0.07	0.88	0.14
Methyl salycilate	3.06	0.23	3.06	0.18	2.98	0.11	3.01	0.16	3.17	0.09
2,6-Dimethoxyphenol	8.06	0.49	7.69	0.24	7.98	1.10	7.39	0.00	7.66	0.35
Furfural	1.48	0.15	2.03	0.15	1.42	0.10	1.19	0.13	1.30	0.09
γ-Decalactone	5.16	0.75	3.60	0.36	3.89	0.55	3.86	0.35	3.86	0.25
δ-Decalactone	15.66	1.05	18.77	1.51	17.72	3.09	14.74	1.16	17.07	2.28

Appendix 3.3.1.6. Concentration and standard deviation (µg/L) of volatile compounds of Area 1 Corvinone wines.

	Yeast 1		Yeast 2		Yeast 3		Yeast 4		Spontaneous	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	104.36	13.96	110.33	1.24	91.85	17.30	67.82	2.03	103.39	11.81
2-Butanol	4080.67	103.33	4778.01	731.57	6011.68	215.35	2716.06	55.06	6474.19	1004.08
1-Pentanol	73.85	1.26	81.61	1.87	72.12	0.37	80.06	0.77	76.03	2.92
Isoamyl alcohol	156916.69	8140.96	176681.52	21715.33	186962.14	14915.80	120782.20	1694.02	160622.13	8400.54
Phenethyl alcohol	13170.04	727.63	14139.50	813.17	13595.22	806.34	10471.27	1232.96	12191.86	153.48
Methionol	573.99	65.60	263.87	19.79	499.98	4.02	568.75	49.86	271.58	10.57
C_6 alcohols										
1-Hexanol	2313.95	89.31	2519.78	58.34	2127.75	14.91	2422.70	2.93	2648.03	151.55
trans-3-Hexen-1-ol	30.09	1.75	36.47	2.02	44.10	2.18	38.70	0.41	23.22	0.59
cis-3-Hexen-1-ol	45.37	7.21	69.46	2.66	61.30	5.48	59.27	7.49	63.00	4.60
cis-2-Hexen-1-ol	13.04	0.28	12.94	0.57	13.42	0.42	13.64	0.32	12.99	0.73
Acetate esters										
Isoamyl acetate	445.65	76.40	561.02	55.76	416.62	6.12	443.38	3.16	485.55	81.76
n-Hexyl acetate	5.78	0.78	8.08	0.09	4.97	0.69	9.97	0.20	7.68	1.39
2-Phenethyl acetate	22.81	0.87	20.25	1.34	19.44	0.79	19.00	1.82	25.49	2.40
Ethyl acetate	32724.56	501.48	43430.90	15312.31	40203.87	46.88	32663.26	6468.05	72443.24	20639.62
Branched-chain fatty acids ethyl esters										
Ethyl 2-methyl butanoate	2.18	0.07	2.96	0.13	3.67	0.21	1.78	0.04	2.32	0.16
Ethyl 3-methyl butanoate	1.77	0.28	2.24	0.34	4.88	0.67	1.54	0.06	2.14	0.16
Fatty acids ethyl esters										
Ethyl butanoate	165.63	21.60	247.91	23.29	168.97	11.94	163.61	47.36	135.33	11.25
Ethyl hexanoate	520.90	138.35	797.21	105.09	569.31	1.63	601.95	46.45	429.34	22.54
Ethyl octanoate	282.00	100.43	402.37	141.67	344.99	9.84	306.05	10.85	231.49	12.04
Ethyl decanoate	68.15	21.82	100.22	7.11	70.07	10.47	75.36	4.00	45.03	1.01
Other esters										
Ethyl 3-hydroxybutanoate	239.60	32.98	288.18	14.26	371.56	2.71	131.22	0.09	252.11	18.07
Ethyl 2-hydroxyhexanoate	0.37	0.02	0.89	0.06	1.24	0.08	0.42	0.03	1.07	0.10
Fatty acids										
3-Methylbutanoic acid	391.60	4.19	404.75	12.46	494.08	53.73	350.12	0.08	305.08	18.17
Hexanoic acid	3647.93	615.24	6145.21	53.94	4300.07	157.32	4148.32	227.00	3271.93	170.77
Octanoic acid	5932.80	606.00	7152.51	415.59	6203.58	46.87	6116.99	296.59	5045.65	36.26
Terpenoids										
cis-Linalooloxide	0.24	0.02	0.12	0.01	0.21	0.01	0.10	0.00	0.26	0.02
trans-Linalooloxide	0.44	0.04	0.64	0.08	0.30	0.03	0.40	0.04	0.43	0.01
Linalool	3.86	0.04	6.02	0.11	4.51	0.01	4.65	0.22	4.73	0.40
Geraniol	5.29	0.30	4.90	0.69	8.24	0.97	11.53	0.89	3.32	0.04
β-Citronellol	10.82	0.88	12.75	1.48	10.44	0.78	7.21	0.88	11.15	0.05
α-Terpineol	0.76	0.10	1.34	0.09	0.96	0.10	0.75	0.06	1.03	0.12
α-Phellandrene	1.43	0.03	1.77	0.05	1.81	0.16	3.19	0.52	1.37	0.01
α-Terpinen	0.02	0.00	0.03	0.00	0.03	0.00	0.04	0.00	0.04	0.01
β-Myrcene	1.86	0.33	2.35	0.14	2.34	0.21	4.14	0.68	1.78	0.01
Limonene	0.18	0.02	0.19	0.01	0.23	0.01	0.30	0.01	0.20	0.00
1,8-Cineol	0.07	0.01	0.10	0.01	0.07	0.00	0.08	0.01	0.06	0.01
p-Cymene	0.11	0.01	0.17	0.03	0.12	0.01	0.13	0.01	0.11	0.01
Terpinolene	0.10	0.01	0.10	0.01	0.12	0.01	0.16	0.01	0.13	0.01
Terpinen-1-ol	0.29	0.02	0.31	0.01	0.27	0.00	0.32	0.01	0.28	0.01
Terpinen-4-ol	0.02	0.00	0.00	0.00	0.02	0.00	0.04	0.01	0.03	0.00
Nerol	0.72	0.04	0.61	0.04	0.68	0.13	0.59	0.02	0.67	0.11
Norisoprenoids										
β-Damascenone	1.60	0.15	1.80	0.08	1.47	0.10	2.14	0.25	1.78	0.14
3-Oxo-α-ionol	1.16	0.01	1.21	0.03	1.20	0.11	1.40	0.06	1.27	0.05
3-Hydroxy-β-damascone	0.09	0.01	0.07	0.00	0.12	0.01	0.09	0.00	0.08	0.01
Vitispirane	0.33	0.04	0.15	0.01	0.50	0.01	0.60	0.01	0.49	0.02
TPB	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
TDN	0.07	0.00	0.06	0.01	0.09	0.01	0.10	0.01	0.09	0.00
Benzenoids and others										
Benzyl Alcohol	26.95	1.43	42.36	1.23	43.91	1.76	36.33	0.45	52.63	4.27
Vanillin	4.85	0.69	4.70	0.49	5.08	0.70	5.45	0.78	4.42	0.41
Vanillyl alcohol	9.45	0.96	14.17	3.36	12.24	2.44	8.83	0.13	13.43	2.39
Ethyl vanillate	156.19	1.63	148.70	5.85	140.02	7.86	99.91	5.70	148.98	1.68
Methyl vanillate	14.92	0.42	14.91	0.44	14.31	0.23	16.01	1.86	14.71	0.12
Benzaldehyde	14.69	0.42	14.54	0.32	14.62	0.04	14.57	0.01	14.46	0.08
Eugenol	0.71	0.12	0.67	0.10	0.76	0.16	0.73	0.03	0.51	0.03
Methyl salycilate	1.63	0.02	1.70	0.01	2.36	0.01	2.04	0.20	2.11	0.07
γ-Decalactone	3.28	0.49	2.93	0.25	2.70	0.15	2.79	0.09	3.02	0.21
δ-Decalactone	13.22	0.75	18.56	1.99	13.81	1.97	14.77	1.90	14.43	1.03
2,6-Dimethoxyphenol	7.80	0.14	10.29	0.49	10.30	0.25	9.00	1.01	10.52	0.23
Furfural	1.49	0.26	2.26	0.40	1.97	0.06	1.78	0.25	1.45	0.11

Appendix 3.3.1.7. Concentration and standard deviation (μg/L) of volatile compounds of Area 2 Corvinone fresh grapes wines.

	Yeast 1		Yeast 2		Yeast 3		Yeast 4		Spontaneous	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	131.94	16.38	114.40	1.87	102.35	4.77	73.87	7.19	96.20	4.69
2-Butanol	4951.13	861.54	5368.33	169.36	7029.57	188.93	3672.23	74.94	7167.72	1027.55
1-Pentanol	77.66	4.46	82.93	3.33	67.65	4.47	66.80	3.99	75.77	1.82
Isoamyl alcohol	176112.82	15320.93	167756.99	147.62	194558.32	13737.71	143779.22	5164.50	158640.69	1414.31
Phenethyl Alcohol	13706.06	1738.29	10643.55	524.84	12352.42	1209.08	12007.38	178.93	11476.68	193.37
Methionol	531.41	69.40	351.46	40.55	552.42	66.48	647.60	16.45	329.99	36.18
C_6 alcohols										
1-Hexanol	3889.71	404.39	4118.86	414.94	3187.19	33.55	2978.89	265.87	4301.85	263.72
trans-3-Hexen-1-ol	57.67	8.17	69.06	4.21	53.13	0.06	43.78	6.38	29.47	1.41
cis-3-Hexen-1-ol	52.40	8.35	65.24	7.35	50.98	8.31	41.68	6.29	41.90	3.36
cis-2-Hexen-1-ol	13.00	1.35	13.57	0.37	12.56	0.29	14.40	0.18	13.04	0.51
Acetate esters										
Isoamyl acetate	438.79	52.55	828.31	64.58	749.99	16.74	389.63	44.82	597.35	121.17
n-Hexyl acetate	10.70	0.59	21.81	0.68	12.59	1.23	12.58	1.23	17.88	2.07
2-Phenethyl acetate	24.86	2.03	26.64	1.53	26.42	1.27	21.71	0.88	35.52	7.75
Ethyl acetate	30479.75	3829.23	37405.76	2927.84	30276.97	6317.38	22150.79	9514.40	90134.73	13811.16
Branched-chain fatty acids ethyl esters										
Ethyl 2-methyl butanoate	3.21	0.40	3.15	0.19	3.79	0.28	2.37	0.21	2.25	0.01
Ethyl 3-methyl butanoate	2.28	0.35	3.89	0.23	5.59	0.74	3.14	0.21	1.64	0.21
Fatty acids ethyl esters										
Ethyl butanoate	142.77	6.11	207.93	29.42	120.71	15.65	140.23	11.20	137.76	3.92
Ethyl hexanoate	511.27	38.58	659.21	23.19	477.27	40.21	492.09	21.96	491.09	19.09
Ethyl octanoate	266.49	35.65	311.05	2.70	259.87	16.40	232.56	4.03	213.64	52.79
Ethyl decanoate	55.05	1.06	63.34	0.28	61.30	3.95	59.40	2.58	38.96	12.01
Other esters										
Ethyl 3-hydroxybutanoate	287.77	1.39	302.23	1.71	366.64	38.80	133.24	0.77	250.95	32.86
Ethyl 2-hydroxyhexanoate	0.56	0.08	0.89	0.04	1.46	0.08	0.42	0.05	0.77	0.07
Fatty acids										
3-Methylbutanoic acid	433.98	92.23	392.91	19.57	582.06	19.77	412.72	57.09	261.50	21.67
Hexanoic acid	3345.15	43.58	4422.53	394.77	2982.90	280.79	3088.65	88.44	3394.91	205.14
Octanoic acid	5453.82	241.59	5751.54	28.21	4989.91	320.95	5072.26	77.56	5107.78	453.48
Terpenoids										
cis-Linalooloxide	0.58	0.04	0.34	0.02	0.45	0.01	0.51	0.06	0.38	0.06
trans-Linalooloxide	0.60	0.08	0.42	0.02	0.52	0.02	0.49	0.03	0.52	0.01
Linalool	7.43	1.05	8.92	0.09	6.34	0.56	6.15	0.64	7.28	0.04
Geraniol	3.82	0.43	3.12	0.12	5.21	0.11	10.02	1.65	4.02	0.16
β-Citronellol	9.23	1.37	10.07	1.46	8.71	0.70	6.54	1.11	8.31	0.58
α-Terpineol	1.84	0.28	2.19	0.22	1.43	0.12	1.36	0.20	1.78	0.09
α-Phellandrene	2.73	0.15	2.28	0.31	2.18	0.40	1.81	0.14	1.31	0.06
α-Terpinen	0.16	0.05	0.07	0.01	0.14	0.02	0.08	0.01	0.06	0.00
β-Myrcene	3.43	0.34	3.01	0.13	2.83	0.29	2.39	0.13	1.70	0.08
Limonene	0.87	0.08	0.73	0.11	0.81	0.15	0.60	0.01	0.54	0.02
1,8-Cineol	0.12	0.01	0.12	0.02	0.13	0.02	0.10	0.01	0.12	0.03
p-Cymene	0.30	0.04	0.20	0.04	0.27	0.04	0.21	0.01	0.15	0.01
Terpinolene	0.28	0.01	0.28	0.00	0.23	0.04	0.25	0.05	0.20	0.01
Terpinen-1-ol	0.29	0.03	0.23	0.04	0.21	0.04	0.31	0.02	0.12	0.16
Terpinen-4-ol	0.32	0.00	0.84	0.06	5.31	1.05	3.34	0.19	2.01	0.01
Nerol	0.02	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Norisoprenoids										
β-Damascenone	2.60	0.09	2.14	0.28	2.01	0.01	1.70	0.15	2.62	0.20
3-Oxo-α-ionol	0.89	0.03	0.83	0.04	0.91	0.04	0.93	0.05	0.89	0.08
3-Hydroxy-β-damascone	0.13	0.01	0.08	0.00	0.10	0.01	0.09	0.01	0.07	0.00
Vitispirane	8.54	0.95	9.93	9.05	11.05	1.24	11.44	2.31	8.77	1.46
TPB	0.07	0.01	0.09	0.08	0.10	0.00	0.11	0.01	0.08	0.02
TDN	1.71	0.20	3.31	0.30	1.65	0.33	1.83	0.30	2.06	0.13
Benzenoids and others										
Benzyl Alcohol	17.32	0.07	10.03	0.85	12.72	1.32	15.85	0.06	14.66	0.04
Vanillin	4.82	0.56	3.88	0.11	5.28	0.22	5.37	0.62	4.25	0.73
Vanillyl alcohol	9.39	0.16	8.97	0.91	7.96	2.25	6.32	0.93	8.25	1.09
Ethyl vanillate	151.67	11.58	162.14	9.35	140.75	2.08	145.67	7.66	153.17	4.89
Methyl vanillate	16.41	0.39	17.48	0.78	14.70	0.64	14.27	0.15	16.62	0.15
Benzaldehyde	14.44	0.22	14.31	0.08	14.34	0.10	14.46	0.01	14.37	0.05
Eugenol	1.11	0.37	1.08	0.25	1.60	0.35	1.04	0.04	0.52	0.02
Methyl salycilate	0.76	0.00	0.68	0.04	0.84	0.11	0.96	0.01	0.24	0.01
2,6-Dimethoxyphenol	10.16	0.64	9.67	0.06	10.05	0.07	10.45	1.12	10.62	0.81
Furfural	1.45	0.06	1.63	0.06	1.52	0.16	1.38	0.04	1.27	0.13
γ-Decalactone	4.27	0.48	3.94	0.08	2.72	0.36	3.10	0.01	3.81	0.41
δ-Decalactone	14.36	0.84	17.00	2.15	14.71	0.18	13.64	1.60	14.47	0.66

Appendix 3.3.1.8. One-Way and Two-Way ANOVA ($p<0,05$) of fresh grapes wine volatile compounds according to employed yeasts and grape origin

	Corvina						Corvinone					
	Area		Yeast		Yeast*Area		Yeast		Area		Yeast*Area	
	Pr > F	*S* [a]	*Pr > F*	*S*	*Pr > F*	*S*	*Pr > F*	*S*	*Pr > F*	*S*	*Pr > F*	*S*
Alcohols												
1-Butanol	0.62	No	0	**Yes**	0	**Yes**	0.36	No	0	**Yes**	0.25	No
2-Butanol	0.93	No	<0.001	**Yes**	0.68	No	0.23	No	<0.001	**Yes**	0.98	No
1-Pentanol	0	**Yes**	0.3	No	0.07	No	0.33	No	0.02	**Yes**	0.01	**Yes**
Isoamyl alcohol	0.23	No	0.01	**Yes**	0.14	No	0.45	No	0	**Yes**	0.29	No
Phenethyl Alcohols	0.42	No	0	**Yes**	0.16	No	0.29	No	0.18	No	0.03	**Yes**
Methionol	0.41	No	<0.001	**Yes**	0.01	**Yes**	0.56	No	<0.001	**Yes**	0.55	No
C_6 Alcohols												
1-Hexanol	<0.001	**Yes**	0.92	No	0.41	No	<0.001	**Yes**	0.53	No	0.03	**Yes**
trans-3-Hexen-1-ol	0	**Yes**	0.1	No	0.04	**Yes**	0.01	**Yes**	0.06	No	0	**Yes**
cis-3-Hexen-1-ol	<0.001	**Yes**	0.7	No	0.61	No	0.05	No	0.09	No	0.07	No
cis-2-Hexen-1-ol	0.02	**Yes**	0.04	**Yes**	0.15	No	0.73	No	0.12	No	0.38	No
Acetate esters												
Isoamyl acetate	0.19	No	0	**Yes**	<0.001	**Yes**	0.04	**Yes**	0.11	No	0.01	**Yes**
n-Hexyl acetate	0.01	**Yes**	0.12	No	<0.001	**Yes**	<0.001	**Yes**	0.5	No	0	**Yes**
2-Phenethyl acetate	0	**Yes**	0.1	No	0	**Yes**	0.01	**Yes**	0.05	No	0.32	No
Ethyl acetate	0.63	No	<0.001	**Yes**	0.72	No	0.63	No	<0.001	**Yes**	0.34	No
Branched-chain fatty acids ethyl esters												
Ethyl 2-methyl butanoate	0	**Yes**	0.03	**Yes**	0	**Yes**	0.32	No	<0.001	**Yes**	0.05	**Yes**
Ethyl 3-methyl butanoate	0.12	No	0	**Yes**	0	**Yes**	0.25	No	<0.001	**Yes**	0.04	**Yes**
Fatty acids ethyl esters												
Ethyl butanoate	0.4	No	0	**Yes**	0.54	No	0.21	No	0.01	**Yes**	0.78	No
Ethyl hexanoate	0.92	No	0.01	**Yes**	0.03	Yes	0.45	No	0.03	**Yes**	0.71	No
Ethyl octanoate	0.07	No	0.03	**Yes**	0.05	No	0.07	No	0.08	No	0.81	No
Ethyl decanoate	0.01	**Yes**	0.15	No	0.08	No	0.07	No	0.03	**Yes**	0.91	No
Other esters												
Ethyl 3-hydroxybutanoate	0.18	No	0	**Yes**	0.02	**Yes**	0.76	No	<0.001	**Yes**	0.4	No
Ethyl 2-hydroxyhexanoate	0.39	No	<0.001	**Yes**	0	**Yes**	0.9	No	<0.001	**Yes**	0	**Yes**
Fatty acids												
3-Methylbutanoic acid	0.25	No	<0.001	**Yes**	0.57	No	0.49	No	<0.001	**Yes**	0.24	No
Hexanoic acid	0.07	No	0.01	**Yes**	0.85	No	0.06	No	0.05	**Yes**	0.39	No
Octanoic acid	0.05	**Yes**	0.03	**Yes**	0.38	No	0.01	**Yes**	0.21	No	0.35	No
Terpenoids												
cis-Linalooloxide	0.01	**Yes**	0.14	No	<0.001	**Yes**	<0.001	**Yes**	0.67	No	0	**Yes**
trans-Linalooloxide	0	**Yes**	0.18	No	0.14	No	0.14	No	0.44	No	0	**Yes**
Linalool	<0.001	**Yes**	0.99	No	0.13	No	<0.001	**Yes**	0.5	No	0.07	No
Geraniol	0.36	No	0.01	**Yes**	0	**Yes**	0.38	No	<0.001	**Yes**	0.18	No
β-Citronellol	0	**Yes**	0.16	No	0.6	No	0.03	**Yes**	0.01	**Yes**	0.74	No
α-Terpineol	<0.001	**Yes**	0.85	No	0.58	No	<0.001	**Yes**	0.31	No	0.13	No
α-Phellandrene	<0.001	**Yes**	0.74	No	0.43	No	<0.001	**Yes**	0.74	No	0	**Yes**
α-Terpinen	<0.001	**Yes**	0.72	No	0.13	No	<0.001	**Yes**	0.72	No	0	**Yes**
β-Myrcene	<0.001	**Yes**	0.56	No	0.8	No	<0.001	**Yes**	0.56	No	0	**Yes**
limonene	<0.001	**Yes**	0.94	No	0.31	No	<0.001	**Yes**	0.94	No	0.01	**Yes**
1,8-Cineol	<0.001	**Yes**	0.48	No	0	**Yes**	<0.001	**Yes**	0.48	No	0.13	No
p-Cymene	<0.001	**Yes**	0.83	No	0.72	No	<0.001	**Yes**	0.83	No	0	**Yes**
Terpinolene	<0.001	**Yes**	0.92	No	0.01	**Yes**	<0.001	**Yes**	0.92	No	0.01	**Yes**
Terpinen-1-ol	0	**Yes**	0.48	No	0.48	No	0	**Yes**	0.48	No	0.32	No
Terpinen-4-ol	0	**Yes**	0.16	No	0.2	No	0	**Yes**	0.16	No	<0.001	**Yes**
Nerol	0	**Yes**	0.11	No	0.06	No	0	**Yes**	**0.11**	No	0.53	No
Norisprenoids												
β-Damascenone	0.65	No	0.14	No	0.03	**Yes**	0.01	**Yes**	0.59	No	0	**Yes**
3-Oxo-α-ionol	<0.001	**Yes**	0.34	No	0.07	No	<0.001	**Yes**	0.88	No	0.18	No
3-Hydroxy-β-damascone	0.34	No	0.01	**Yes**	<0.001	**Yes**	0.63	No	0	**Yes**	0	**Yes**
Vitispirane	<0.001	**Yes**	0.89	No	0	**Yes**	<0.001	**Yes**	0.89	No	0.95	No
TPB	<0.001	**Yes**	0.57	No	0.06	No	<0.001	**Yes**	0.57	No	0.84	No
TDN	<0.001	**Yes**	0.93	No	<0.001	**Yes**	<0.001	**Yes**	0.93	No	0	**Yes**
Benzenoids and others												
Benzyl Alcohols	0	**Yes**	0.33	No	0.01	**Yes**	<0.001	**Yes**	0.9	No	<0.001	**Yes**
Vanillin	0.01	**Yes**	0.02	**Yes**	0.18	No	0.54	No	0.03	**Yes**	0.77	No
Vanillyl Alcohols	0.06	No	0.71	No	0.16	No	0	**Yes**	0.32	No	0.27	No
Ethyl vanillate	0.09	No	0.27	No	0.24	No	0.13	No	0.02	**Yes**	0	**Yes**
Methyl vanillate	0.09	No	0.16	No	0	**Yes**	0.08	No	0.36	No	0.01	**Yes**
Benzaldehyde	0.02	**Yes**	0.34	No	0.22	No	0.01	**Yes**	0.8	No	0.93	No
Eugenol	<0.001	**Yes**	0.87	No	0.01	**Yes**	<0.001	**Yes**	0.89	No	<0.001	**Yes**
Methyl salycilate	<0.001	**Yes**	0.86	No	0.07	No	<0.001	**Yes**	0.86	No	0.13	No
2,6-Dimethoxyphenol	0.01	**Yes**	0.35	No	0.53	No	0.16	No	0.19	No	0.03	**Yes**
Furfural	0.97	No	0	**Yes**	0.01	**Yes**	0.3	No	0.77	No	0.91	No
γ-Decalactone	0	**Yes**	0.36	No	0.16	No	0.01	**Yes**	0.05	No	0.15	No
δ-Decalactone	0.88	No	0.22	No	0.51	No	0.67	No	0.3	No	0.94	No

[a]: Significance according to ANOVA analysis.

Appendix 3.3.1.9. Significantly different compounds according to ANOVA analysis (α=0.05) between Spontaneous and inoculated (Yeast 1, yeast 2, yeast 3, yeast 4) fermentations in fresh grapes wines.

	Area 1 Corvina	**Area 2 Corvina**	**Area 1 Corvinone**	**Area 2 Corvinone**
	S[a]	*S*[a]	*S*[a]	*S*[a]
Alcohols				
Methionol	No	No	**Yes**	No
C_6 Alcohols				
1-Hexanol	No	No	**Yes**	No
Trans-3-Hexen-1-ol	**Yes**	**Yes**	**Yes**	**Yes**
Acetate esters				
2-Phenethyl acetate	No	**Yes**	**Yes**	**Yes**
Ethyl acetate	**Yes**	**Yes**	**Yes**	**Yes**
Fatty acids ethyl esters				
Decanoic acid ethyl ester	**Yes**	No	**Yes**	**Yes**
Acids				
3-Methylbutanoic acid	**Yes**	**Yes**	**Yes**	**Yes**
Octanoic acid	No	No	**Yes**	No
Terpenoids				
cis-Linalooloxide	**Yes**	**Yes**	No	No
β-Citronellol	No	**Yes**	No	No
α-Phellandrene	No	No	No	**Yes**
β-Myrcene	No	No	No	**Yes**
p-Cymene	No	No	No	**Yes**
Terpinolene	No	**Yes**	No	**Yes**
Terpinen-1-ol	No	No	No	**Yes**
Norisprenoids				
3-Oxo-α-ionol	**Yes**	No	No	No
Vitispirane	No	**Yes**	No	No
TPB	No	**Yes**	-	-
TDN	No	**Yes**	No	No
Benzenoids				
Furfural	**Yes**	No	No	**Yes**
Benzyl Alcohols	No	No	**Yes**	No
Eugenol	No	No	No	**Yes**
Methyl salycilate	No	No	**Yes**	**Yes**

[a]: Significance according to ANOVA analysis.

Appendix 3.3.1.10. p-Values of significantly different compounds between HCA clusters according to Mann-Withney test (α=0.05) in fresh grapes wines.

	Corvina			**Corvinone**		
	Cluster 1-Cluster 2	Cluster 1-Cluster 3	Cluster 2-Cluster 3	Cluster 1-Cluster 2	Cluster 1-Cluster 3	Cluster 2-Cluster 3
Alcohols	**0.048**	0.094	0.354	0.825	0.536	0.412
C_6 alcohols	0.432	**0.029**	0.171	**0.003**	**0.001**	0.648
Acetate esters	0.343	0.613	0.524	0.414	**0.000**	**0.006**
Ethyl esters	0.268	**0.014**	0.171	0.414	0.837	0.648
Branched-chain fatty acid ethyl esters	1.000	0.694	0.833	0.414	0.252	0.788
Other esters	0.876	0.694	0.943	0.940	0.142	0.073
Ethyl acetate	0.202	0.536	0.127	0.050	0.606	**0.042**
Organic acid	0.202	**0.009**	0.127	0.106	0.470	0.648
Cyclic terpenes	0.530	0.397	0.524	**0.003**	**0.001**	0.527
Linear terpenes	0.639	0.694	0.354	0.582	0.737	0.927
Norisoprenoids	0.639	**0.014**	0.127	**0.003**	**0.008**	0.927
Benzenoids	0.149	0.121	0.833	0.940	0.351	0.648
Others	0.876	0.336	0.524	0.260	**0.023**	0.412

Appendix 3.3.2.1. Enological parameters of Corvina and Corvinone withered grapes musts at crush

	PAN[a] (mg/L)		**AMMONIA (mg/L)**		**YAN[b] (mg/L)**		**Glucose + fructose (g/L)**		**pH**	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Area 1 Corvina	111.9 c	7.8	36.8 c	2.4	142.2 c	9.3	243.8 c	3.1	3.17 c	0.03
Area 2 Corvina	105.0 c	5.4	46.3 b	6.2	143.1 c	6.4	291.2 a	3.6	3.36 a	0.04
Area 1 Corvinone	149.3 a	8.4	73.9 a	4.4	210.1 a	11.3	235.1d	2.4	3.02 d	0.01
Area 2 Corvinone	124.1 b	9.1	49.9 b	3.6	165.1 b	11.8	254.9 b	4.2	3.25 b	0.01

[a] PAN: Primary Amino Nitrogen; [b]YAN: Yeast Assimilable Nitrogen. Different letters denote statistically significant difference as obtained by ANOVA (α=0.05) with post-hoc Tukey test

Appendix 3.3.2.2. Enological parameters of withered grapes wines at the end of alcoholic fermentation.

		Yeast 1		**Yeast 2**		**Yeast 3**		**Yeast 4**		**Spontaneous**	
		mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Area 1 Corvina	Total acidity (g/L)	6.7	0.1	7.7	0.1	6.7	0.1	7.4	0.1	7.8	1.9
	pH	3.01	0.01	3.08	0.01	3.07	0.01	3.07	0.01	3.09	0.02
	Acetic acid (g/L)	0.28	0.02	0.30	0.00	0.37	0.04	0.39	0.01	0.89	0.01
	Ethanol (% v/v)	13.97	0.31	14.17	0.09	13.92	0.42	14.26	0.31	14.15	0.30
Area 2 Corvina	Total acidity (g/L)	7.6	0.7	10.3	0.3	7.8	0.1	7.6	0.2	7.8	0
	pH	2.98	0.01	2.99	0.01	2.98	0.02	2.98	0.00	2.92	0.01
	Acetic acid (g/L)	0.20	0.11	0.47	0.18	0.37	0.18	0.13	0.01	0.89	0.06
	Ethanol (% v/v)	13.91	0.40	13.73	0.09	13.86	0.11	13.68	0.08	13.41	0.24
Area 1 Corvinone	Total acidity (g/L)	5.8	0.1	7.2	0.2	6.4	0	6	0	6.2	0.3
	pH	3.35	0.06	3.30	0.01	3.32	0.01	3.31	0.02	3.23	0.01
	Acetic acid (g/L)	0.50	0.04	0.60	0.07	0.59	0.01	0.44	0.03	0.85	0.01
	Ethanol (% v/v)	17.04	0.17	17.07	0.35	16.84	0.31	16.54	0.09	16.96	0.02
Area 2 Corvinone	Total acidity (g/L)	6.	0.4	7.8	0.1	6.6	0.1	7.0	0.0	6.8	0.4
	pH	3.2	0.0	3.2	0.0	3.2	0.0	3.2	0.0	3.2	0.0
	Acetic acid (g/L)	0.2	0.0	0.4	0.2	0.3	0.0	0.2	0.0	0.8	0.0
	Ethanol (% v/v)	15.2	0.1	14.8	0.0	14.9	0.4	15.0	0.2	15.1	0.5

Appendix 3.3.2.3. One-way and two-way ANOVA analysis (α=0.05) of enological parameters of withered grapes wines at the end of alcoholic fermentation.

	Corvina						**Corvinone**					
	Area		**Yeast**		**Area*Yeast**		**Area**		**Yeast**		**Area*Yeast**	
	Pr > F	S[a]	Pr > F	S[a]	Pr > F	S[a]	Pr > F	S[a]	Pr > F	S[a]	Pr > F	S[a]
Total acidity	0.009	Yes	0.159	No	0.589	No	<0.0001	Yes	<0.0001	Yes	0.024	Yes
pH	<0.0001	Yes	0.278	No	0.003	Yes	<0.0001	Yes	0.001	Yes	0.018	Yes
Acetic acid	<0.0001	Yes	<0.0001	Yes	0.000	Yes	0.357	No	<0.0001	Yes	0.932	No
Ethanol	<0.0001	Yes	0.685	No	0.340	Yes	<0.0001	Yes	0.568	No	0.383	No

[a]: Significance according to ANOVA analysis.

Appendix 3.3.2.4. Concentration (μg/L) and standard deviation (± μg/L) of volatile compounds of Area 1 Corvina withered grapes wines

	Yeast 1		Yeast 2		Yeast 3		Yeast 4		Spontaneous	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	371.05	14.63	241.87	9.91	186.51	6.10	241.95	3.30	146.94	2.74
2-Butanol	4090.42	127.27	4366.08	114.18	7199.53	88.06	4483.68	86.56	4814.56	106.43
1-Pentanol	41.94	2.13	44.76	0.83	46.75	2.60	46.35	3.87	52.11	0.41
Isoamyl alcohol	260081.23	5159.37	270951.21	10672.92	294794.22	1927.05	256675.98	4262.01	123499.88	565.52
Phenylethyl Alcohol	24746.76	917.32	17689.79	400.08	20823.48	605.37	23562.84	2108.59	9503.41	146.24
Methionol	105.27	4.96	84.92	5.44	123.47	14.62	143.71	3.83	33.01	1.29
C_6 alcohols										
1-Hexanol	954.18	9.50	948.77	8.58	902.40	8.26	853.42	15.13	768.00	24.98
trans-3-Hexen-1-ol	9.30	0.02	9.92	0.94	10.55	0.59	11.07	0.26	6.79	0.35
cis-3-Hexen-1-ol	43.27	1.94	40.99	0.93	44.51	1.95	39.98	1.09	40.64	1.39
cis-2-Hexen-1-ol	18.26	0.17	15.85	0.70	16.41	1.18	16.84	0.79	16.23	1.92
Acetate esters										
Isoamyl acetate	287.14	4.84	417.00	6.83	365.18	25.42	342.91	3.76	663.35	12.79
n-Hexyl acetate	19.11	0.08	51.72	2.94	18.96	0.12	17.36	0.36	23.57	1.29
2-Phenethyl acetate	23.91	2.09	18.75	0.72	19.87	0.37	23.83	2.04	44.81	0.71
Ethyl acetate	58494.57	2695.41	83656.17	5855.87	64511.68	7287.26	41856.25	1930.06	128728.91	3263.81
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	3.41	0.12	2.73	1.39	3.38	0.01	3.17	0.23	0.90	0.14
Ethyl -3-methylbutanoate	2.57	0.01	2.95	0.19	2.73	0.08	2.79	0.21	1.05	0.07
Fatty acids ethyl esters										
Ethyl butanoate	260.10	29.42	422.74	22.32	251.05	11.19	184.12	0.15	95.45	1.34
Ethyl hexanoate	361.31	15.52	555.12	23.57	414.17	24.71	271.97	11.41	176.53	5.61
Ethyl octanoate	171.19	15.40	309.87	24.84	247.56	2.04	148.21	7.71	89.70	3.05
Ethyl lactate	225.35	7.00	236.10	20.09	284.54	2.35	203.32	12.91	359.76	0.62
Ethyl decanoate	65.28	5.73	42.70	1.45	45.31	2.35	14.25	1.29	17.94	0.08
Other esters										
Ethyl 3-hydroxybutanoate	148.56	7.57	247.18	15.42	227.89	12.49	139.87	6.30	78.60	2.91
Ethyl 2-hydroxyhexanoate	0.42	0.02	1.23	0.16	1.52	0.10	1.01	0.00	0.53	0.01
Fatty acids										
3-Methylbutanoic acid	424.86	19.17	310.26	9.60	439.13	20.92	414.41	11.50	547.27	5.76
Hexanoic acid	1824.83	50.37	2973.50	117.13	2209.76	14.81	1509.15	23.80	941.09	29.54
Octanoic acid	3537.02	193.32	4631.18	308.33	4100.89	2.94	3219.52	27.57	2216.20	164.18
Terpenoids										
cis-Linaloloxide	0.55	0.05	0.10	0.01	0.08	0.02	0.02	0.00	0.68	0.03
trans-Linaloloxide	0.96	0.07	0.03	0.01	0.05	0.03	0.16	0.13	0.62	0.04
Linalool	5.76	1.00	6.98	0.42	5.81	0.36	5.07	0.13	5.06	0.10
Geraniol	2.23	0.13	3.50	0.69	3.35	0.62	2.67	0.14	3.01	0.32
α-Terpineol	3.50	0.00	3.90	0.52	2.82	0.33	3.22	0.13	2.81	0.40
β-citronellol	26.76	3.07	8.57	1.70	13.30	1.49	16.31	0.43	15.69	1.77
α-Phellandrene	3.35	0.27	3.66	0.16	3.16	0.06	1.26	0.06	3.20	0.14
α-Terpinen	0.13	0.01	0.16	0.01	0.11	0.01	0.45	0.07	0.14	0.00
β-Myrcene	4.36	0.35	5.65	0.35	3.89	0.23	2.83	0.04	4.80	1.10
Limonene	0.74	0.04	0.93	0.08	0.63	0.04	0.67	0.02	0.78	0.16
1,4-Cineol	0.00	0.00	0.00	0.00	0.04	0.00	0.43	0.03	0.09	0.01
1,8-Cineol	0.08	0.00	0.04	0.06	0.13	0.01	0.05	0.01	0.08	0.01
p-Cymene	0.32	0.01	0.39	0.01	0.28	0.02	0.52	0.02	0.39	0.01
Terpinolene	0.47	0.08	0.59	0.02	0.45	0.07	0.52	0.01	0.52	0.04
Terpinen-4-ol	0.48	0.04	0.47	0.09	1.21	0.15	14.11	0.01	0.75	0.07
Norisoprenoids										
β-damascenone	8.33	1.56	8.38	1.17	5.09	0.30	6.87	0.16	6.01	0.81
3-Hydroxy-β-damascone	0.21	0.01	0.40	0.04	0.28	0.09	0.36	0.04	0.30	0.01
Vitispirane	3.45	0.21	3.88	0.18	2.66	0.04	3.62	0.02	3.10	0.99
TPB	0.04	0.01	0.04	0.00	0.03	0.01	0.04	0.00	0.02	0.00
TDN	0.73	0.03	0.78	0.13	0.50	0.06	0.69	0.03	0.57	0.07
Benzenoids and others										
Benzyl alcohol	279.52	13.31	296.78	13.09	316.75	7.83	307.61	26.40	251.22	11.33
Vanillin	5.50	0.00	5.52	0.12	5.43	0.15	5.54	0.16	2.00	0.07
Ethyl-vanillate	127.88	5.50	119.02	3.81	123.33	3.86	124.45	2.86	126.81	5.37
Methyl-vanillate	5.46	0.20	8.72	0.63	5.17	0.76	6.23	0.23	5.49	0.52
Benzaldehyde	16.14	1.19	20.31	1.63	16.66	0.59	17.85	0.70	70.95	7.71
Eugenol	7.01	0.04	7.32	0.02	7.26	0.00	7.14	0.22	6.45	0.49
Methyl salycilate	0.99	0.16	1.12	0.31	0.63	0.01	0.74	0.05	0.39	0.07
2.6-Dimethoxy-phenol	5.30	0.55	5.42	0.37	6.29	0.16	6.39	0.18	5.02	0.16
Furfural	1.38	0.06	1.24	0.09	1.89	0.00	1.17	0.18	0.69	0.04
Others										
γ-decalactone	2.36	0.16	2.41	0.13	2.27	0.00	2.73	0.01	2.15	0.19
δ-decalactone	32.99	2.51	31.19	1.33	28.78	1.27	30.24	3.59	23.71	2.13

Appendix 3.3.2.5 Concentration (µg/L) and standard deviation (± µg/L) of volatile compounds of Area 2 Corvina withered grapes wines										
	Yeast 1		**Yeast 2**		**Yeast 3**		**Yeast 4**		**Spontaneous**	
	mean	*sd*	*mean*	*sd*	*mean*	*sd*	*mean*	*sd*	*mean*	*sd*
Alcohols										
1-Butanol	441.60	12.31	220.49	9.52	190.27	8.34	205.29	9.91	290.30	14.21
2-Butanol	3487.83	19.06	4174.76	194.86	4787.57	1.14	3691.44	374.75	5230.78	139.41
1-Pentanol	36.54	3.17	46.36	2.33	47.77	6.75	43.88	3.17	53.30	16.89
Isoamyl alcohol	224667.89	6776.42	229712.89	18302.19	223202.09	16502.44	207073.25	31666.64	230409.47	52366.99
Phenylethyl Alcohol	23779.32	783.16	21426.04	2421.59	21909.83	450.40	21160.97	707.81	22770.98	707.11
Methionol	102.96	3.90	98.07	9.43	127.90	5.51	153.40	17.46	162.44	107.20
C_6 alcohols										
1-Hexanol	838.43	25.46	781.33	10.08	712.71	4.66	798.18	16.11	763.07	26.74
trans-3-Hexen-1-ol	7.30	0.41	7.90	0.24	6.53	0.43	7.31	0.42	6.82	1.25
cis-3-Hexen-1-ol	38.18	3.79	39.27	1.43	34.32	0.60	38.98	1.32	39.13	4.83
cis-2-Hexen-1-ol	16.33	1.27	16.70	0.50	15.82	0.24	16.70	0.08	16.24	0.14
Acetate esters										
Isoamyl acetate	201.22	3.98	310.27	1.60	305.31	3.94	302.26	18.75	342.06	165.76
n-Hexyl acetate	20.18	1.35	38.97	1.15	22.50	2.48	22.36	1.57	32.38	3.58
2-Phenethyl acetate	22.27	0.41	25.38	1.02	22.87	1.31	14.91	2.82	19.87	0.33
Ethyl acetate	51966.16	5386.41	62889.15	7084.72	52042.64	476.92	48505.44	1117.42	152996.10	14625.14
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	3.50	0.09	3.86	0.68	3.99	0.11	2.22	0.13	1.80	0.33
Ethyl -3-methylbutanoate	4.07	0.08	3.96	0.09	4.08	0.21	3.83	0.10	3.97	0.08
Fatty acids ethyl esters										
Ethyl butanoate	232.99	3.66	244.30	3.06	170.31	6.74	160.74	7.11	172.36	21.39
Ethyl hexanoate	342.78	2.55	391.36	10.20	280.57	14.14	232.48	3.34	265.86	95.90
Ethyl octanoate	232.65	16.50	296.96	3.34	201.46	6.02	152.80	1.60	182.44	49.89
Ethyl lactate	244.39	18.96	246.63	7.59	236.89	3.22	193.08	7.44	336.42	28.96
Ethyl decanoate	70.89	1.82	82.04	7.63	56.46	3.37	29.78	6.25	36.49	4.51
Other esters										
Ethyl 3-hydroxybutanoate	105.64	6.74	134.61	0.52	65.35	0.66	77.05	16.40	83.53	2.35
Ethyl 2-hydroxyhexanoate	0.25	0.02	0.54	0.06	0.43	0.00	0.46	0.04	0.36	0.24
Fatty acids										
3-Methylbutanoic acid	318.40	7.15	328.26	33.71	388.00	3.51	319.32	21.51	269.95	123.81
Hexanoic acid	2030.04	44.08	1844.35	46.25	1451.38	138.40	1316.03	152.40	1338.87	293.02
Octanoic acid	4261.98	68.70	3990.88	62.36	3355.84	49.80	3190.36	183.16	3272.96	553.04
Terpenoids										
cis-Linaloloxide	0.09	0.01	0.09	0.03	0.07	0.04	0.04	0.01	0.06	0.01
trans-Linaloloxide	0.24	0.01	0.06	0.02	0.05	0.01	0.03	0.00	0.09	0.00
Linalool	6.45	0.63	12.31	0.06	10.42	0.35	10.16	0.02	8.81	0.21
Geraniol	2.81	0.11	4.25	0.16	3.03	0.06	3.21	0.21	3.02	0.49
α-Terpineol	5.21	0.01	10.13	0.52	6.46	0.33	4.42	0.26	3.98	0.16
β-citronellol	14.28	0.25	10.02	0.18	9.40	0.81	9.18	0.39	9.02	1.48
α-Phellandrene	5.70	0.23	10.37	0.98	5.92	0.57	6.62	0.26	6.70	0.28
α-Terpinen	0.20	0.00	0.68	0.54	0.20	0.00	0.19	0.01	0.20	0.01
β-Myrcene	7.31	0.43	13.46	1.27	7.69	0.74	8.59	0.34	8.70	0.36
Limonene	1.38	0.05	2.51	0.14	1.36	0.11	1.46	0.10	1.26	0.02
1,4-Cineol	0.00	0.00	0.05	0.00	0.08	0.00	0.06	0.01	0.06	0.00
1,8-cineol	0.12	0.02	0.19	0.01	0.09	0.00	0.09	0.01	0.08	0.01
p-Cymene	0.39	0.04	0.55	0.01	0.45	0.03	0.40	0.03	0.34	0.10
Terpinolene	0.84	0.05	1.64	0.23	0.84	0.05	0.85	0.04	0.75	0.05
Terpinen-4-ol	1.23	0.04	1.17	0.06	2.44	0.20	1.59	0.18	1.16	1.12
Norisoprenoids										
β-damascenone	3.34	0.13	5.00	0.26	2.81	0.16	2.89	0.13	2.23	0.20
3-Hydroxy-β-damascone	0.31	0.04	0.13	0.02	0.16	0.01	0.16	0.01	0.29	0.08
Vitispirane	1.83	0.08	4.01	0.18	1.59	0.07	1.56	0.12	0.76	0.21
TPB	0.02	0.00	0.06	0.01	0.02	0.00	0.02	0.00	0.01	0.00
TDN	0.32	0.02	0.75	0.06	0.24	0.03	0.23	0.03	0.13	0.00
Benzenoids and others										
Benzyl alcohol	199.41	1.32	223.31	21.96	193.43	0.15	233.75	2.73	256.88	5.20
Vanillin	4.97	0.02	4.97	0.06	4.90	0.19	4.87	0.15	4.88	0.14
Ethyl-vanillate	135.24	4.24	143.78	4.97	137.46	5.40	140.60	7.06	143.45	4.02
Methyl-vanillate	4.71	0.10	6.05	0.60	5.92	0.39	6.00	0.80	4.39	0.20
Benzaldehyde	15.42	0.74	15.45	0.39	15.60	0.86	16.59	1.25	15.47	1.19
Eugenol	6.55	0.35	6.28	0.01	5.46	0.01	5.14	0.17	6.00	0.02
Methyl salycilate	3.64	0.07	5.73	0.09	2.32	0.05	2.99	0.08	2.35	0.17
2,6-Dimethoxy-phenol	6.51	0.01	6.57	0.69	5.51	0.16	5.30	0.45	5.78	0.89
Furfural	1.68	0.11	2.06	0.35	1.54	0.08	1.43	0.12	1.53	0.13
γ-decalactone	2.60	0.14	2.25	0.01	2.36	0.15	2.44	0.07	2.26	0.01
δ-decalactone	25.14	8.63	21.78	2.94	25.17	3.28	23.91	0.01	23.58	1.71

Appendix 3.3.2.6. Concentration (μg/L) and standard deviation (± μg/L) of volatile compounds of Area 1 Corvinone withered wines

	Yeast 1		Yeast 2		Yeast 3		Yeast 4		Spontaneous	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols										
1-Butanol	326.74	172.01	228.80	28.38	158.29	15.66	100.38	4.53	141.27	17.97
2-Butanol	5643.65	610.53	4982.00	428.99	5859.68	54.54	3285.67	159.30	10321.02	654.72
1-Pentanol	48.14	0.59	43.09	3.20	46.67	7.15	59.99	4.31	42.16	1.04
Isoamyl alcohol	254284.54	8385.71	271359.59	10095.38	284435.71	27643.96	200643.47	13644.73	179624.61	7028.64
Phenylethyl Alcohol	21325.75	994.00	19427.48	29.11	19265.06	2092.85	20947.90	993.69	14671.16	1348.06
Methionol	221.98	5.51	135.32	28.73	222.60	31.58	389.66	73.67	51.24	15.38
C_6 alcohols										
1-Hexanol	2020.95	110.53	1940.31	3.38	1737.24	135.60	1701.42	125.04	1710.03	34.29
trans-3-Hexen-1-ol	27.90	1.53	27.90	0.91	29.85	0.43	25.66	1.57	17.26	3.01
cis-3-Hexen-1-ol	17.83	0.05	20.29	1.92	19.81	1.68	18.76	1.36	19.12	4.82
cis-2-Hexen-1-ol	16.54	0.03	15.05	0.83	14.73	0.55	16.21	0.88	15.78	1.07
Acetate esters										
Isoamyl acetate	382.14	9.68	707.32	20.52	482.77	29.00	258.90	31.35	547.90	4.36
n-Hexyl acetate	17.77	0.84	14.17	1.07	8.98	0.74	12.35	2.60	11.60	0.49
2-Phenethyl acetate	35.58	0.69	29.21	0.07	25.74	1.08	24.61	1.47	42.36	1.78
Ethyl acetate	64373.17	10729.73	101319.97	11629.39	62124.08	15222.96	44992.66	1170.91	159826.78	858.73
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	1.80	0.35	3.57	0.21	2.46	0.31	1.21	0.21	0.89	0.16
Ethyl -3-methylbutanoate	3.13	0.01	3.10	0.16	3.22	0.13	3.06	0.09	3.19	0.10
Fatty acids ethyl esters										
Ethyl butanoate	159.71	5.76	206.20	1.07	184.08	12.60	168.03	9.72	125.35	16.24
Ethyl hexanoate	288.88	34.73	441.20	3.88	371.86	22.02	294.37	1.03	136.72	21.62
Ethyl octanoate	130.27	11.62	204.82	17.71	182.78	16.91	117.46	7.09	63.44	3.55
Ethyl lactate	467.73	59.32	685.54	32.99	502.66	4.44	415.45	8.14	1047.19	10.42
Ethyl decanoate	31.85	2.35	45.66	2.81	54.99	2.70	29.99	3.01	6.92	1.84
Other esters										
Ethyl 3-hydroxybutanoate	219.48	14.79	291.85	20.39	373.57	19.01	169.63	3.90	36.88	0.49
Ethyl 2-hydroxyhexanoate	0.40	0.10	1.36	0.03	1.22	0.02	0.66	0.03	0.22	0.09
Fatty acids										
3-Methylbutanoic acid	323.93	49.67	364.47	17.78	486.21	29.49	253.57	14.10	363.79	279.85
Hexanoic acid	1882.76	89.07	2938.93	68.25	2359.40	124.09	1986.87	33.29	1022.20	80.26
Octanoic acid	3576.79	173.28	4432.38	27.19	4197.55	25.65	3798.66	22.14	1735.40	831.93
Terpenoids										
cis-Linaloloxide	0.11	0.08	0.06	0.02	0.08	0.04	0.05	0.02	0.95	1.24
trans-Linaloloxide	0.07	0.01	0.03	0.01	0.08	0.08	0.04	0.01	0.32	0.26
Linalool	4.36	0.19	5.06	0.50	4.49	0.30	1.55	0.07	5.05	0.25
Geraniol	0.83	0.25	1.14	0.26	1.15	0.21	1.32	0.17	1.10	0.17
α-Terpineol	3.19	0.57	3.57	0.53	4.06	0.67	3.37	0.04	3.39	0.11
β-citronellol	5.62	1.79	4.58	0.16	7.25	0.38	3.68	0.04	3.53	0.64
α-Phellandrene	1.08	0.01	1.38	0.07	1.74	0.17	0.41	0.01	2.19	0.42
α-Terpinen	0.06	0.01	0.09	0.01	0.09	0.02	0.22	0.02	0.10	0.01
β-Myrcene	1.40	0.03	1.80	0.09	2.26	0.23	2.64	0.11	2.85	0.54
Limonene	0.40	0.01	0.46	0.02	0.61	0.11	0.85	0.04	0.69	0.08
1,4-Cineol	0.03	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,8-cineol	0.09	0.01	0.08	0.01	0.00	0.00	0.00	0.00	0.09	0.01
p-Cymene	0.16	0.02	0.24	0.01	0.22	0.03	0.26	0.03	0.25	0.03
Terpinolene	0.27	0.03	0.33	0.01	0.35	0.02	0.53	0.02	0.36	0.02
Terpinen-4-ol	0.11	0.01	0.12	0.01	0.82	0.02	0.10	0.00	0.26	0.06
Norisoprenoids										
β-damascenone	5.46	0.07	5.45	0.92	10.30	0.28	7.93	1.32	9.07	0.06
3-Hydroxy-β-damascone	0.18	0.02	0.16	0.05	0.26	0.01	0.24	0.01	0.14	0.01
Vitispirane	9.77	0.66	10.79	1.84	11.99	3.46	16.45	0.47	13.37	0.69
TPB	0.07	0.01	0.08	0.01	0.18	0.01	0.17	0.01	0.12	0.02
TDN	1.81	0.01	1.76	0.37	3.69	0.21	3.70	0.01	2.78	0.42
Benzenoids and others										
Benzyl alcohol	45.93	4.19	35.16	1.95	44.49	2.60	56.89	5.24	72.90	2.55
Vanillin	6.06	0.25	5.94	0.22	5.94	0.06	5.88	0.17	6.04	0.08
Ethyl-vanillate	182.83	18.82	172.96	1.77	189.04	7.86	170.44	4.26	191.00	20.58
Methyl-vanillate	11.69	0.74	9.33	0.24	14.28	1.34	11.61	0.53	12.30	0.12
Benzaldehyde	14.50	0.22	14.30	0.19	15.03	0.21	14.75	0.00	14.60	0.14
Eugenol	1.90	0.01	1.88	0.13	2.01	0.28	1.88	0.11	1.88	0.11
Methyl salycilate	1.52	0.18	1.57	0.25	3.92	0.01	3.05	0.06	2.48	0.12
2,6-Dimethoxy-phenol	5.28	0.06	5.07	0.12	4.83	0.37	5.04	0.39	6.11	0.27
Furfural	0.67	0.07	1.04	0.72	0.97	0.10	0.97	0.04	0.63	0.15
γ-decalactone	2.47	0.17	3.30	0.28	3.09	0.32	2.32	0.11	2.34	0.02
δ-decalactone	17.63	3.57	23.47	2.17	20.19	1.21	18.71	0.62	14.87	0.81

Appendix 3.3.2.7. Concentration (μg/L) and standard deviation (± μg/L) of volatile compounds of Area 2 Corvinone withered grapes wines

	Yeast 1		Yeast 2		Yeast 3		Yeast 4		Spontaneous	
	mean	*sd*	*mean*	*sd*	*mean*	*sd*	*mean*	*sd*	*mean*	*sd*
Alcohols										
1-Butanol	435.89	5.62	246.54	7.13	202.54	3.61	161.62	28.98	203.59	32.91
2-Butanol	3865.04	40.39	4224.78	295.96	4888.37	123.11	4074.09	56.97	4692.72	419.96
1-Pentanol	69.68	10.63	53.39	3.74	51.05	1.63	40.72	1.02	36.36	1.58
Isoamyl alcohol	257950.60	8007.71	324624.88	25095.93	266038.52	4144.07	312923.60	9347.07	218748.18	20124.22
Phenylethyl Alcohol	21673.35	295.90	26484.00	2343.37	20012.78	156.67	24689.13	1023.65	15005.66	57.25
Methionol	116.97	4.76	217.18	60.02	129.93	9.23	259.07	18.89	69.61	2.59
C_6 alcohols										
1-Hexanol	1149.65	29.59	1424.44	70.95	1054.97	33.81	1154.77	40.13	1189.48	53.31
trans-3-Hexen-1-ol	15.01	1.16	19.05	1.02	13.65	0.96	18.31	0.26	13.40	1.28
cis-3-Hexen-1-ol	11.12	0.28	15.55	0.16	11.72	0.59	15.26	0.30	13.78	1.94
cis-2-Hexen-1-ol	16.00	0.44	15.68	0.33	16.11	0.35	17.28	0.94	15.07	0.94
Acetate esters										
Isoamyl acetate	702.55	31.55	689.58	45.25	450.43	15.25	373.92	23.64	708.08	37.99
n-Hexyl acetate	10.75	1.54	12.18	3.84	8.81	2.03	17.77	0.24	14.02	2.14
2-Phenethyl acetate	26.14	2.51	26.53	2.86	14.21	1.85	14.32	2.01	32.92	2.21
Ethyl acetate	57699.07	1624.57	70315.11	9727.01	69853.24	1595.82	54018.15	6668.26	158498.39	2588.87
Branched-chain fatty acids ethyl esters										
Ethyl-2-methylbutanoate	1.83	0.04	2.53	0.04	2.31	0.14	2.93	0.09	1.12	0.08
Ethyl -3-methylbutanoate	3.11	0.14	3.10	0.13	3.21	0.16	2.95	0.08	3.10	0.18
Fatty acids ethyl esters										
Ethyl butanoate	267.28	27.74	366.95	11.50	201.25	3.67	241.66	12.76	262.34	21.33
Ethyl hexanoate	415.84	14.28	567.81	45.25	358.27	11.13	439.93	23.36	364.84	50.11
Ethyl octanoate	221.11	6.07	320.36	68.82	236.13	6.18	282.17	7.74	198.47	11.00
Ethyl lactate	226.73	7.34	443.77	29.85	206.46	8.03	277.63	36.13	531.84	41.32
Ethyl decanoate	51.72	7.74	85.86	5.85	67.95	2.79	75.81	10.45	48.74	6.30
Other esters										
Ethyl 3-hydroxybutanoate	198.08	5.95	266.81	20.89	215.93	5.90	168.82	12.93	128.57	28.39
Ethyl 2-hydroxyhexanoate	0.31	0.04	1.42	0.04	0.66	0.06	0.84	0.06	0.33	0.04
Fatty acids										
3-Methylbutanoic acid	374.47	10.27	432.56	57.91	364.05	17.82	459.10	2.18	282.97	14.81
Hexanoic acid	2194.09	377.72	3172.54	401.13	2056.21	65.63	2299.39	149.00	1868.12	27.08
Octanoic acid	4021.06	130.90	5095.48	359.10	3948.40	101.82	4166.92	87.94	3786.14	46.03
Terpenoids										
cis-Linaloloxide	0.07	0.02	0.11	0.06	0.10	0.01	0.04	0.01	0.08	0.01
trans-Linaloloxide	0.08	0.07	0.04	0.00	0.03	0.00	0.08	0.00	0.05	0.01
Linalool	5.34	0.19	6.44	0.05	6.30	0.29	6.52	0.52	5.55	0.66
Geraniol	1.09	0.20	1.67	0.24	1.75	0.21	1.75	0.26	1.68	0.30
α-Terpineol	3.08	0.07	4.18	0.11	4.30	0.32	3.51	0.13	3.41	0.30
β-citronellol	10.93	0.36	6.57	0.17	7.82	0.84	7.94	0.42	6.92	0.28
α-Phellandrene	2.90	0.16	2.79	0.04	3.07	0.18	3.45	0.35	2.97	0.24
α-Terpinen	0.09	0.01	0.14	0.12	0.05	0.00	0.06	0.01	0.05	0.01
β-Myrcene	3.76	0.21	3.68	0.04	3.98	0.24	4.48	0.45	3.89	0.27
Limonene	0.68	0.05	0.66	0.08	0.71	0.04	0.72	0.04	0.67	0.03
1,4-Cineol	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,8-cineol	0.09	0.00	0.11	0.01	0.10	0.01	0.08	0.01	0.09	0.01
p-Cymene	0.24	0.01	0.16	0.01	0.15	0.00	0.15	0.00	0.17	0.02
Terpinolene	0.33	0.05	0.22	0.03	0.31	0.01	0.29	0.02	0.27	0.03
Terpinen-4-ol	1.59	0.03	0.05	0.01	0.06	0.01	0.05	0.00	0.06	0.01
Norisoprenoids										
β-damascenone	3.19	0.08	2.77	0.15	2.87	0.04	3.03	0.25	2.54	0.23
3-Hydroxy-β-damascone	0.12	0.01	0.15	0.00	0.10	0.01	0.11	0.01	0.15	0.05
Vitispirane	3.56	0.28	4.42	0.14	3.43	0.14	3.54	0.17	3.44	0.23
TPB	0.02	0.00	0.02	0.00	0.02	0.00	0.02	0.00	0.02	0.00
TDN	0.33	0.04	0.34	0.03	0.24	0.01	0.26	0.01	0.26	0.02
Benzenoids and others										
Benzyl alcohol	39.17	0.30	34.19	1.61	31.11	3.26	52.14	5.28	56.54	0.81
Vanillin	5.45	0.07	5.54	0.16	5.49	0.21	5.60	0.21	5.50	0.14
Ethyl-vanillate	177.78	4.48	185.85	22.39	145.92	19.79	184.34	21.53	180.38	33.66
Methyl-vanillate	10.56	0.22	13.24	0.30	11.47	0.72	12.80	1.77	12.04	1.13
Benzaldehyde	14.50	0.09	15.03	0.69	14.19	0.49	14.84	0.24	14.80	0.11
Eugenol	1.26	0.01	1.26	0.01	1.16	0.06	1.26	0.01	1.68	0.01
Methyl salycilate	0.64	0.07	0.77	0.04	0.63	0.13	0.64	0.08	0.37	0.02
2,6-Dimethoxy-phenol	6.70	0.42	5.66	0.53	5.11	0.65	6.98	0.03	5.99	0.37
Furfural	1.79	0.08	2.10	0.10	1.62	0.12	1.86	0.19	1.35	0.19
γ-decalactone	2.25	0.00	3.20	0.16	2.47	0.30	3.02	0.11	2.32	0.08
δ-decalactone	22.06	0.52	28.68	4.83	16.57	2.34	28.13	2.51	23.11	2.44

Appendix 3.3.2.8. Kruskal Wallis (p<0,05) of volatile compounds according to employed yeasts and grape origin in withered grapes wines.

	Corvina		**Corvinone**	
	Yeast	**Area**	**Yeast**	**Area**
	S[a]	*S*[a]	*S*[a]	*S*[a]
Alcohols				
1-Butanol	**Yes**	No	**Yes**	No
2-Butanol	**Yes**	No	No	**Yes**
1-Pentanol	No	No	No	No
Isoamyl alcohol	No	No	**Yes**	No
Phenylethyl Alcohol	No	No	**Yes**	No
Methionol	No	No	**Yes**	No
C_6 alcohols				
1-Hexanol	No	**Yes**	No	**Yes**
trans-3-Hexen-1-ol	No	**Yes**	No	**Yes**
cis-3-Hexen-1-ol	No	**Yes**	No	**Yes**
cis-2-Hexen-1-ol	No	No	No	No
Acetate esters				
Isoamyl acetate	No	**Yes**	**Yes**	No
n-Hexyl acetate	**Yes**	No	No	No
2-Phenethyl acetate	No	No	**Yes**	**Yes**
Ethyl acetate	**Yes**	No	**Yes**	No
Branched-chain fatty acids ethyl esters				
Ethyl-2-methylbutanoate	**Yes**	No	**Yes**	No
Ethyl 3-methylbutanoate	No	**Yes**	No	No
Fatty acids ethyl esters				
Ethyl butanoate	**Yes**	No	No	**Yes**
Ethyl hexanoate	**Yes**	No	**Yes**	**Yes**
Ethyl octanoate	**Yes**	No	No	**Yes**
Ethyl decanoate	**Yes**	No	No	**Yes**
Ethyl lactate	**Yes**	No	**Yes**	**Yes**
Other esters				
Ethyl 3-hydroxybutanoate	No	**Yes**	**Yes**	No
Ethyl 2-hydroxyhexanoate	No	**Yes**	**Yes**	No
Fatty acids				
3-Methylbutanoic acid	No	**Yes**	No	No
Hexanoic acid	**Yes**	No	**Yes**	No
Octanoic acid	**Yes**	No	**Yes**	No
Terpenoids				
cis-Linaloloxide	**Yes**	No	No	No
trans-Linaloloxide	**Yes**	No	No	No
Linalool	No	**Yes**	No	**Yes**
Geraniol	**Yes**	No	No	**Yes**
α-Terpineol	No	**Yes**	**Yes**	No
β-citronellol	No	**Yes**	No	**Yes**
α-Phellandrene	No	**Yes**	No	**Yes**
α-Terpinen	No	**Yes**	No	**Yes**
β-Myrcene	No	**Yes**	No	**Yes**
Limonene	No	**Yes**	No	No
1,4-Cineol	**Yes**	No	**Yes**	No
1,8-cineol	No	No	No	**Yes**
p-Cymene	No	No	No	**Yes**
Terpinolene	No	**Yes**	No	**Yes**
Terpinen-4-ol	**Yes**	No	No	**Yes**
Norisoprenoids				
β-damascenone	No	**Yes**	No	**Yes**
3-Hydroxy-β-damascone	No	**Yes**	No	**Yes**
Vitispirane	No	**Yes**	No	**Yes**
TPB	**Yes**	No	No	**Yes**
TDN	No	**Yes**	No	**Yes**
Benzenoids and others				
Benzyl alcohol	No	**Yes**	**Yes**	No
Vanillin	No	**Yes**	No	**Yes**
Ethyl-vanillate	No	**Yes**	No	No
Methyl-vanillate	**Yes**	No	No	No
Benzaldehyde	No	**Yes**	No	No
Eugenol	No	**Yes**	No	**Yes**
Methyl salycilate	No	**Yes**	No	**Yes**
2,6-Dimethoxy-phenol	No	No	No	**Yes**
Furfural	No	**Yes**	No	**Yes**
γ-decalactone	No	No	**Yes**	No
δ-decalactone	No	**Yes**	No	**Yes**

[a]: Significance according to ANOVA analysis.

Appendix 3.3.2.9. Significantly different compounds according to Kruskal Wallis analysis (α=0.05) between Spontaneous and inoculated (Yeast 1, yeast 2, yeast 3, yeast 4) fermentations in withered grapes wines.

	Area 1 Corvina	**Area 2 Corvina**	**Area 1 Corvinone**	**Area 2 Corvinone**
Alcohols	*S*[a]	*S*[a]	*S*[a]	*S*[a]
1-Butanol	**Yes**	No	No	No
2-Butanol	No	**Yes**	**Yes**	No
1-Pentanol	**Yes**	No	0,192	**Yes**
Isoamyl alcohol	**Yes**	No	**Yes**	**Yes**
Phenylethyl Alcohol	**Yes**	No	**Yes**	**Yes**
Methionol	No	No	**Yes**	**Yes**
C_6 alcohols				
1-Hexanol	**Yes**	No	No	No
trans-3-Hexen-1-ol	**Yes**	No	**Yes**	No
Acetate esters				
Isoamyl acetate	**Yes**	No	No	No
n-Hexyl acetate	No	No	No	No
2-Phenethyl acetate	**Yes**	No	**Yes**	**Yes**
Ethyl acetate	**Yes**	**Yes**	**Yes**	**Yes**
Branched-chain fatty acids ethyl esters				
Ethyl-2-methylbutanoate	**Yes**	**Yes**	**Yes**	**Yes**
Ethyl 3-methylbutanoate	**Yes**	No	No	No
Fatty acids ethyl esters				
Ethyl butanoate	**Yes**	No	**Yes**	No
Ethyl hexanoate	**Yes**	No	**Yes**	No
Ethyl octanoate	**Yes**	No	**Yes**	**Yes**
Ethyl decanoate	No	No	**Yes**	No
Ethyl lactate	**Yes**	**Yes**	**Yes**	**Yes**
Other esters				
Ethyl 3-hydroxybutanoate	**Yes**	No	**Yes**	**Yes**
Ethyl 2-hydroxyhexanoate	No	No	**Yes**	No
Fatty acids				
3-Methylbutanoic acid	**Yes**	No	No	**Yes**
Hexanoic acid	**Yes**	No	**Yes**	**Yes**
Octanoic acid	**Yes**	No	**Yes**	**Yes**
Terpenoids				
cis-Linaloloxide	**Yes**	No	No	No
trans-Linaloloxide	No	No	**Yes**	No
α-Terpineol	No	**Yes**	No	No
α-Phellandrene	No	No	**Yes**	No
Limonene	No	**Yes**	No	No
1,8-cineol	No	**Yes**	No	No
Terpinolene	No	**Yes**	No	No
Norisoprenoids				
β-damascenone	No	**Yes**	No	No
Vitispirane	No	**Yes**	No	No
TPB	**Yes**	**Yes**	No	No
TDN	No	**Yes**	No	No
Benzenoids and others				
Benzyl alcohol	**Yes**	**Yes**	**Yes**	**Yes**
Vanillin	**Yes**	No	No	No
Methyl-vanillate	No	**Yes**	No	No
Benzaldehyde	**Yes**	No	No	No
Eugenol	**Yes**	No	No	**Yes**
Methyl salycilate	**Yes**	No	No	**Yes**
2,6-Dimethoxy-phenol	No	No	**Yes**	No
Furfural	**Yes**	No	No	**Yes**
δ-decalactone	**Yes**	No	No	No

[a]: Significance according to ANOVA analysis

Appendix 3.3.2.10. Significantly different compounds according to ANOVA (α=0.05) between different yeast considering different batches of withered grapes wines individually.

	Corvina Area 1	**Corvina Area 2**	**Corvinone Area 1**	**Corvinone Area 2**
	S[a]	*S*[a]	*S*[a]	*S*[a]
Alcohols				
1-Butanol	**Yes**	**Yes**	No	**Yes**
2-Butanol	**Yes**	**Yes**	**Yes**	**Yes**
1-Pentanol	No	No	**Yes**	**Yes**
Isoamyl alcohol	**Yes**	No	**Yes**	**Yes**
Phenylethyl Alcohol	**Yes**	No	**Yes**	**Yes**
Methionol	**Yes**	No	**Yes**	**Yes**
C_6 alcohols				
1-Hexanol	**Yes**	**Yes**	No	**Yes**
trans-3-Hexen-1-ol	**Yes**	No	**Yes**	**Yes**
cis-3-Hexen-1-ol	No	No	No	**Yes**
cis-2-Hexen-1-ol	No	No	No	No
Acetate esters				
Isoamyl acetate	**Yes**	No	**Yes**	**Yes**
n-Hexyl acetate	**Yes**	**Yes**	**Yes**	No
2-Phenethyl acetate	**Yes**	**Yes**	**Yes**	**Yes**
Ethyl acetate	**Yes**	**Yes**	**Yes**	**Yes**
Branched-chain fatty acids ethyl esters				
Ethyl-2-methylbutanoate	**Yes**	**Yes**	**Yes**	**Yes**
Ethyl 3-methylbutanoate	**Yes**	No	No	No
Fatty acids ethyl esters				
Ethyl butanoate	**Yes**	**Yes**	**Yes**	**Yes**
Ethyl hexanoate	**Yes**	No	**Yes**	**Yes**
Ethyl octanoate	**Yes**	**Yes**	**Yes**	No
Ethyl decanoate	**Yes**	**Yes**	**Yes**	**Yes**
Ethyl lactate	**Yes**	**Yes**	**Yes**	**Yes**
Other esters				
Ethyl 3-hydroxybutanoate	**Yes**	**Yes**	**Yes**	**Yes**
Ethyl 2-hydroxyhexanoate	**Yes**	No	**Yes**	**Yes**
Fatty acids				
3-Methylbutanoic acid	**Yes**	No	No	**Yes**
Hexanoic acid	**Yes**	**Yes**	**Yes**	**Yes**
Octanoic acid	**Yes**	**Yes**	**Yes**	**Yes**
Terpenoids				
cis-Linaloloxide	**Yes**	No	No	No
trans-Linaloloxide	**Yes**	**Yes**	No	No
Linalool	No	**Yes**	**Yes**	No
Geraniol	No	**Yes**	No	No
α-Terpineol	No	**Yes**	No	**Yes**
β-citronellol	**Yes**	**Yes**	**Yes**	**Yes**
α-Phellandrene	**Yes**	**Yes**	**Yes**	No
α-Terpinen	**Yes**	No	**Yes**	No
β-Myrcene	**Yes**	**Yes**	**Yes**	No
Limonene	No	**Yes**	**Yes**	No
1,4-Cineol	**Yes**	**Yes**	**Yes**	**Yes**
1,8-cineol	No	**Yes**	**Yes**	No
p-Cymene	**Yes**	**No**	**Yes**	**Yes**
Terpinolene	No	**Yes**	**Yes**	No
Terpinen-4-ol	**Yes**	No	**Yes**	**Yes**
Norisoprenoids				
β-damascenone	No	**Yes**	**Yes**	No
Vitispirane	No	**Yes**	No	**Yes**
TPB	**Yes**	**Yes**	**Yes**	No
TDN	No	**Yes**	**Yes**	**Yes**
3-Hydroxy-β-damascone	No	**Yes**	**Yes**	No
Benzenoids				
Benzyl alcohols and others	**Yes**	**Yes**	**Yes**	**Yes**
Vanillin	**Yes**	No	No	No
Ethyl-vanillate	No	No	No	No
Methyl-vanillate	**Yes**	**Yes**	**Yes**	No
Benzaldehyde	**Yes**	No	No	No
Eugenol	No	**Yes**	No	**Yes**
Methyl salycilate	**Yes**	**Yes**	**Yes**	**Yes**
2,6-Dimethoxy-phenol	**Yes**	No	**Yes**	**Yes**
Furfural	**Yes**	No	No	**Yes**
γ-decalactone	**Yes**	No	**Yes**	**Yes**
δ-decalactone	No	No	No	**Yes**

[a]: Significance according to ANOVA analysis

Appendix 3.3.2.11. p-Values of significantly different compounds between HCA clusters according to Mann-Withney test (α=0.05) in withered grapes wines.

	Corvina			**Corvinone**		
	Cluster 1-Cluster 2	Cluster 1-Cluster 3	Cluster 2-Cluster 3	Cluster 1-Cluster 2	Cluster 1-Cluster 3	Cluster 2-Cluster 3
Alcohols	0.073	**0.000**	0.283	0.154	0.721	0.368
C6 alcohols	**0.004**	**0.000**	0.461	**0.004**	**0.002**	0.368
Acetate esters	0.214	**0.021**	0.109	0.933	0.130	0.570
Ethyl esters	0.073	0.328	0.109	0.808	0.195	0.283
Branched chain	**0.032**	**0.005**	**0.004**	0.933	0.328	0.214
Other esters	**0.004**	**0.000**	0.570	0.109	0.083	0.933
Ethyl Acetate	**0.004**	0.234	**0.004**	0.683	0.065	**0.004**
Fatty acids	**0.016**	0.161	**0.048**	0.808	0.721	0.368
Linear terpenes	0.683	0.505	0.154	**0.004**	**0.021**	**0.008**
Cyclic terpenes	0.683	**0.015**	**0.048**	**0.004**	**0.000**	0.154
Norisoprenoids	**0.028**	**0.002**	0.808	**0.004**	**0.021**	0.808
Benzenoids	0.283	**0.000**	**0.004**	0.933	0.878	0.808
Others	**0.004**	**0.003**	0.933	0.073	0.959	0.214

Appendix 4.3.1. Concentration (μg/L) and standard deviation (± μg/L) of free acompounds of T16 and T40 2017 fresh Corvina wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	76.22	5.22	108.12	4.27	64.72	18.37	109.20	5.51	109.11	2.57	60.26	17.65	107.43	2.47	84.73	5.55	108.13	0.45	98.89	1.51
Isoamyl alcohol	226282.36	28872.52	183083.27	10200.09	314807.28	13562.19	243940.72	1425.63	302733.88	2665.89	180513.22	49398.01	179836.06	5234.95	277615.10	51333.87	243325.78	906.71	278089.55	14399.83
1-Pentanol	69.27	1.48	69.18	1.27	35.77	4.63	70.89	11.33	80.68	15.06	55.96	24.38	78.27	2.03	64.67	0.63	67.96	1.61	71.87	14.44
Phenylethyl alcohol	19058.85	3461.15	12924.53	584.10	29141.34	13194.46	22402.95	373.40	22277.07	416.36	16071.34	4483.09	12320.68	182.67	26481.66	4433.43	21955.83	55.00	20875.50	1114.64
Methionol	338.09	13.17	386.67	4.11	406.38	85.35	478.52	3.69	282.72	4.19	358.03	105.52	416.31	14.20	350.90	14.80	552.82	9.69	346.56	4.38
C_6 alcohols																				
1-Hexanol	1962.99	40.30	1693.02	25.76	1581.53	110.93	1190.55	11.98	2050.80	81.13	1561.70	450.42	1652.32	33.99	1656.30	20.97	1222.38	30.38	1950.00	47.94
trans-3-Hexen-1-ol	9.39	0.40	9.85	0.44	8.34	0.99	7.07	0.06	12.70	0.24	7.45	2.10	10.54	0.32	9.47	0.22	7.09	0.26	12.61	0.86
cis-3-Hexen-1-ol	737.38	9.21	663.37	3.10	647.19	11.60	597.15	7.80	943.46	35.87	576.43	166.07	645.96	14.18	647.83	14.91	610.71	9.70	876.89	21.60
cis-2-Hexen-1-ol	1.43	0.02	12.30	0.98	15.33	0.63	13.17	0.48	16.30	1.81	2.82	0.30	14.19	0.71	13.80	0.21	15.14	0.33	7.29	3.43
Esters																				
Isoamyl acetate	251.39	8.46	257.18	0.93	148.28	34.73	456.66	10.05	596.29	19.60	129.65	36.48	126.20	3.97	147.45	6.44	280.91	11.13	226.15	3.23
2-Phenethyl acetate	32.66	0.52	23.79	0.12	37.57	6.35	37.21	0.38	45.00	0.63	22.94	3.64	19.63	0.31	25.86	0.39	31.17	0.09	27.26	0.50
n-Hexyl acetate	0		0		0		0		0		0		0		0		0		0	
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	21.18	0.02	8.68	0.62	17.33	4.33	18.14	0.87	21.67	0.96	45.04	12.46	20.58	1.51	70.51	0.06	46.43	0.36	52.27	1.54
Ethyl-3-methylbutanoate	24.21	0.94	9.28	0.14	20.68	3.44	20.33	0.88	28.29	1.07	47.82	13.72	22.81	1.17	73.26	1.42	49.28	1.53	62.32	2.03
Ethyl fatty acids esters																				
Ethyl butanoate	111.93	0.36	98.54	1.58	76.13	15.76	142.15	2.95	212.62	7.75	108.02	30.32	108.52	2.32	154.05	6.55	171.92	2.58	223.88	7.81
Ethyl hexanoate	221.70	4.83	216.64	0.82	189.20	67.72	340.70	9.57	510.38	9.75	197.35	56.82	186.02	3.73	263.23	4.08	317.85	5.74	503.68	8.70
Ethyl octanoate	117.63	3.48	120.25	1.36	164.44	35.57	180.66	9.00	252.96	9.05	64.46	17.90	66.49	1.01	65.77	1.53	91.45	3.13	140.75	6.93
Ethyl decanoate	17.87	0.08	20.70	0.34	18.20	4.30	22.99	0.86	27.22	1.25	4.80	1.20	8.19	0.03	3.71	0.26	7.23	0.32	8.20	1.31
Ethyl-3-hydroxybutanoate	213.29	2.58	210.63	3.63	271.03	51.50	201.72	0.81	244.96	5.13	150.51	47.88	184.39	5.93	170.73	5.43	185.05	2.74	195.97	5.78
Ethyl lactate	2928.65	0.22	3066.02	35.15	2823.89	96.75	2230.02	29.67	2974.98	106.02	3284.60	995.57	4581.28	162.84	3471.94	73.63	3320.59	47.68	3438.00	81.56
Fatty acids																				
3-Methylbutanoic acid	528.82	5.46	360.52	3.76	798.00	174.52	640.40	17.76	506.29	9.22	390.29	117.35	349.23	12.92	524.23	11.28	631.66	5.71	445.94	8.94
Hexanoic acid	2301.71	50.97	2174.80	6.52	3428.21	979.28	3308.18	24.50	4527.56	128.05	1688.60	500.87	2115.85	43.73	2299.98	53.25	3336.01	61.31	4161.56	108.60
Octanoic acid	1660.89	22.81	1502.91	11.98	578.59	402.50	2177.28	14.69	3205.36	53.47	1187.98	354.96	1417.65	16.53	1232.07	55.00	2158.11	40.16	2840.84	160.45
Terpenes																				
trans-Linaloloxide	4.37	0.11	4.25	0.08	4.01	0.11	5.83	0.21	6.14	0.78	34.79	15.59	12.33	0.21	13.32	0.71	5.82	0.60	18.81	1.47
cis-Linaloloxide	3.12	0.15	2.27	0.27	2.39	0.03	1.33	0.59	3.06	0.16	11.09	1.30	6.87	0.19	6.03	0.14	2.83	0.21	9.89	0.58
Linalool	49.66	0.76	47.59	0.16	40.01	0.52	35.02	0.14	55.31	0.36	11.99	0.01	7.3	0.14	28.17	0.05	17.69	0.11	20.62	0.01
α-Terpineol	7.83	0.36	7.57	0.23	5.27	0.00	2.12	0.10	10.26	0.78	7.14	0.17	7.23	0.14	4.56	0.17	3.17	0.46	6.78	0.02
β-Citronellol	4.07	0.24	3.01	0.18	2.67	0.20	3.84	0.38	3.37	0.03	0.56	0.06	0.79	0.07	0.47	0.05	0.88	0.02	0.39	0.01
Geraniol	2.60	0.03	2.59	0.12	1.24	0.05	1.17	0.03	1.55	0.11	0.44	0.02	0.83	0.01	0.28	0.02	0.29	0.01	0.13	0.01
α-Terpinen	0		0		0		0		0		0		0		0		0		0	
1,4-Cineole	0.05	0.00	0.03	0.01	0.06	0.01	0.03	0.00	0.04	0.01	0.18	0.01	0.12	0.01	0.20	0.01	0.15	0.00	0.15	0.01
Limonene	1.93	0.11	1.70	0.05	1.19	0.05	1.11	0.13	2.42	0.16	0.70	0.07	0.83	0.15	0.54	0.03	0.75	0.06	0.76	0.03
1,8-Cineole	0.13	0.02	0.14	0.02	0.07	0.00	0.06	0.00	0.20	0.01	0.31	0.02	0.28	0.03	0.20	0.01	0.24	0.03	0.32	0.01
p-Cymene	0.33	0.06	0.24	0.00	0.22	0.01	0.26	0.02	0.35	0.02	0.20	0.02	0.21	0.04	0.16	0.01	0.17	0.03	0.15	0.00
Terpinen-4-ol	1.00	0.02	0.46	0.00	1.14	0.03	0.34	0.01	0.59	0.01	0.93	0.06	0.51	0.04	0.92	0.02	0.41	0.03	0.60	0.01
p-Menthane-1,8-diol	0.00		0.00		0.00		0.00		0.00		18.42	6.05	23.11	0.98	16.84	0.39	12.94	0.60	28.82	0.46
Noirsoprenoids																				
β-Damascenone	1.70	0.15	3.27	0.06	1.87	0.03	1.11	0.22	1.47	0.10	2.11	0.29	2.81	0.44	2.26	0.09	1.70	0.18	1.39	0.08
3-Hydroxy-βdamascone	0		0		0		0		0		0		0		0		0		0	
Vitispirane	38.37	9.58	55.24	1.17	71.45	8.63	25.67	5.29	57.61	5.73	275.41	35.51	186.88	40.55	168.09	11.91	173.60	0.02	137.10	1.03
TPB	1.32	0.25	2.44	0.04	2.22	0.18	1.00	0.20	1.35	0.07	5.90	0.31	10.53	1.48	5.92	0.22	7.16	0.11	3.25	0.04
TDN	9.72	8.64	38.92	0.97	38.85	6.26	15.63	3.03	25.11	2.46	232.61	21.20	229.44	45.18	113.99	11.72	164.86	27.51	76.22	14.79
3-Oxo-α-ionol	2.28	0.02	2.43	0.01	1.95	0.26	1.89	0.01	1.29	0.11	1.46	0.35	2.51	0.01	1.88	0.06	1.80	0.03	1.42	0.07
Benzenoids																				
Furfural	5.79	0.09	3.66	0.71	2.99	0.53	4.09	0.23	4.54	0.30	60.26	17.74	161.81	6.57	61.12	1.72	65.89	1.34	36.12	0.27
Benzaldehyde	19.04	0.29	16.89	0.01	15.66	0.73	16.24	0.23	16.28	0.04	16.96	0.85	18.27	0.50	16.25	0.23	15.92	0.24	16.03	0.09
Benzyl alcohol	87.44	2.63	71.05	3.09	79.64	33.80	88.89	2.97	77.92	10.47	61.64	9.23	82.53	1.40	74.37	9.66	95.18	9.90	71.20	4.99
Vanillin	32.80	13.14	16.38	1.98	12.70	3.66	32.10	6.69	15.78	1.13	11.18	2.59	12.24	1.43	12.96	2.28	11.08	0.19	9.90	0.38
Methyl-vanillate	9.36	0.13	6.40	0.84	5.92	1.46	6.61	0.19	13.49	0.16	8.07	1.61	5.77	0.06	5.72	0.48	6.45	0.12	13.07	0.32
Ethyl-vanillate	94.53	2.58	103.91	0.48	128.49	35.75	51.89	0.18	90.24	2.38	82.70	23.42	97.42	4.72	106.66	5.86	57.68	1.15	85.83	15.99
Methyl salycilate	0.30	0.03	0.16	0.01	0.17	0.01	0.52	0.05	0.48	0.02	0.43	0.04	0.20	0.04	0.31	0.01	0.59	0.05	0.47	0.00
2,6-Dimethoxy-phenol	5.68	0.00	5.98	0.13	6.59	1.55	5.77	0.24	5.38	0.31	9.52	2.32	9.75	0.17	9.95	0.63	9.64	0.11	8.48	0.33
Eugenol	4.09	0.37	0.61	0.04	3.93	1.37	0.84	0.08	0.60	0.16	1.03	0.57	0.65	0.09	0.92	0.06	0.42	0.05	0.42	0.07
Others																				
γ-Nonalactone	14.87	1.13	15.24	0.31	18.44	6.57	9.63	0.01	12.09	0.21	12.16	1.62	14.77	0.14	15.29	0.48	9.72	0.15	11.03	0.05

V1-5 is short for Vineyards 1-5

Appendix 4.3.2. Concentration (µg/L) and standard deviation (± µg/L) of free compounds of T16 and T40 2017 fresh Corvinone wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	82.09	3.91	121.18	35.57	94.07	14.57	148.96	4.00	100.19	7.42	79.55	0.79	108.08	2.14	65.98	9.79	148.32	3.16	95.94	2.15
Isoamyl alcohol	233832.91	7523.09	229589.98	34574.74	252078.84	13485.32	245730.29	17915.17	240152.81	30060.53	235089.19	1647.47	195735.30	7914.25	224795.90	54442.71	247875.90	1068.36	247970.97	3256.11
1-Pentanol	87.74	10.42	144.05	1.04	52.42	1.84	104.44	1.31	95.43	0.33	89.35	4.39	102.77	1.96	77.77	9.72	112.83	17.95	90.89	8.02
Phenylethyl alcohol	20735.48	234.31	16585.27	732.31	24375.89	595.79	22291.69	1746.03	19163.12	2343.59	21226.37	272.02	15779.45	735.48	28750.22	175.00	22261.70	101.01	19981.25	20.40
Methionol	431.61	22.97	284.90	7.22	647.78	38.94	479.83	13.95	267.54	141.98	536.70	40.36	502.67	9.43	359.46	52.38	674.13	20.38	613.99	0.52
C_6 alcohols																				
1-Hexanol	2153.06	67.16	2383.04	211.35	1875.05	82.18	1983.16	44.54	2360.87	75.71	2285.19	12.35	2186.08	23.54	1566.83	108.25	2039.17	14.35	2336.62	18.81
trans-3-Hexen-1-ol	17.58	0.45	24.31	5.21	17.67	0.52	14.80	0.35	23.05	0.01	18.73	0.22	20.14	0.26	15.14	0.61	16.18	0.15	22.01	0.05
cis-3-Hexen-1-ol	84.34	4.87	24.31	4.55	51.56	1.52	66.26	0.21	59.14	1.09	91.37	0.26	57.30	0.80	49.05	3.65	66.74	1.20	60.92	0.20
cis-2-Hexen-1-ol	12.20	0.91	5.55	0.64	12.03	0.79	8.03	4.45	14.30	1.34	14.08	0.57	13.13	0.16	13.87	0.72	13.26	0.47	12.35	0.48
Esters																				
Isoamyl acetate	215.49	7.86	257.07	3.91	188.24	31.21	571.25	9.59	256.22	1.89	159.80	5.43	137.43	0.41	89.79	15.17	367.10	0.57	108.24	2.02
2-Phenethyl acetate	30.17	0.44	26.38	1.03	30.68	3.41	30.35	0.40	35.19	0.75	25.92	0.79	20.94	0.24	26.04	3.37	26.51	0.28	22.29	0.36
n-Hexyl acetate	0		0		0		0		0		0		0		0		0		0	
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	17.80	0.06	9.71	0.06	10.33	1.14	8.80	0.65	12.36	0.38	45.92	2.72	23.36	0.20	28.31	5.49	21.48	0.28	31.73	1.13
Ethyl-3-methylbutanoate	19.17	1.59	6.71	1.71	14.88	1.56	9.75	0.83	13.88	0.69	41.77	1.47	27.54	0.93	37.72	5.91	24.72	0.38	34.14	2.32
Ethyl fatty acids esters																				
Ethyl butanoate	93.21	1.56	83.00	5.18	93.89	6.27	183.99	1.82	109.09	6.27	122.86	0.04	101.99	0.45	100.21	13.11	195.26	0.59	119.05	1.76
Ethyl hexanoate	194.98	3.21	203.18	4.50	216.62	36.38	453.72	9.78	270.33	5.47	221.05	0.88	176.05	1.88	180.80	20.77	397.54	3.60	252.11	0.04
Ethyl octanoate	110.48	3.84	112.75	4.86	138.33	7.24	246.78	1.35	161.14	5.05	56.45	2.53	53.89	1.30	71.37	7.06	124.02	8.28	75.98	0.66
Ethyl decanoate	12.12	0.75	25.68	8.59	22.53	3.36	25.05	1.12	19.17	0.65	3.67	0.24	5.56	0.00	4.61	0.46	10.77	1.70	4.22	0.39
Ethyl-3-hydroxybutanoate	199.84	8.78	193.63	9.02	350.10	0.74	264.10	8.15	253.68	3.58	185.22	12.33	199.40	0.09	202.31	33.75	248.66	9.37	199.44	7.29
Ethyl lactate	2303.77	86.94	1836.27	29.03	3408.50	458.80	1707.70	10.61	2872.68	30.93	3252.39	160.55	3600.81	52.17	4469.96	529.18	3217.65	91.79	3992.92	37.90
Fatty acids																				
3-Methylbutanoic acid	516.90	13.24	376.13	20.92	645.68	3.45	450.59	16.64	402.97	0.17	522.92	21.81	382.98	6.82	319.91	14.84	446.92	5.37	37.67	0.16
Hexanoic acid	2193.08	67.19	2184.55	143.13	3645.17	277.44	3947.14	124.91	2558.82	16.26	2304.20	3.04	2075.97	5.11	3539.39	388.24	4072.51	17.56	2431.83	33.88
Octanoic acid	1359.93	41.96	1543.27	159.96	1225.96	967.37	2753.76	79.48	1981.84	9.10	1403.03	52.36	1344.10	10.73	2767.72	274.98	2814.67	19.22	1884.42	38.88
Terpenes																				
trans-Linaloloxide	1.89	0.25	1.62	0.08	3.98	1.46	6.86	6.86	1.79	0.05	6.32	0.20	5.74	0.46	6.01	0.27	7.74	4.69	6.43	0.04
cis-Linaloloxide	1.20	0.04	1.02	0.01	0.78	0.02	0.00	0.00	1.06	0.11	2.67	0.06	3.16	0.07	2.36	0.11	3.59	0.46	3.06	0.27
Linalool	22.82	0.36	14.60	0.05	15.50	0.12	12.65	3.87	25.84	0.06	17.76	0.05	6.04	0.04	12.67	0.01	11.52	0.09	13.48	0.08
α-Terpineol	3.15	0.17	1.42	0.04	1.94	0.14	1.44	1.44	4.03	0.01	3.10	0.04	2.53	0.19	2.31	0.00	2.95	0.21	4.23	0.14
β-Citronellol	2.56	0.11	2.83	0.18	3.01	0.13	6.81	6.81	3.05	0.08	0.48	0.01	0.86	0.01	0.42	0.02	2.50	0.24	0.56	0.04
Geraniol	1.08	0.05	1.54	0.12	1.66	0.08	4.58	4.58	1.19	0.09	0.18	0.01	0.46	0.00	0.59	0.02	0.95	0.02	0.39	0.06
α-Terpinen	0		0		0		0		0		0		0		0		0		0	
1,4-Cineole	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.05	0.00	0.04	0.01	0.08	0.00	0.05	0.00	0.05	0.01
Limonene	0.59	0.05	0.37	0.01	0.46	0.04	0.42	0.42	0.93	0.02	0.31	0.00	0.32	0.03	0.23	0.02	0.52	0.02	0.49	0.05
1,8-Cineole	0.05	0.00	0.02	0.01	0.04	0.00	0.00	0.00	0.06	0.00	0.11	0.00	0.09	0.01	0.11	0.00	0.07	0.01	0.16	0.02
p-Cymene	0.18	0.03	0.08	0.01	0.30	0.01	0.04	0.04	0.14	0.01	0.07	0.01	0.13	0.03	0.07	0.01	0.11	0.01	0.24	0.17
Terpinen-4-ol	0.48	0.00	0.25	0.01	0.79	0.06	0.34	0.34	0.56	0.01	0.40	0.01	0.32	0.02	0.58	0.02	0.31	0.05	0.43	0.03
p-Menthane-1,8-diol	0.00		0.00		0.00		0.00		0.00		7.42	0.82	3.32	0.04	7.46	1.44	0.88	0.29	9.01	0.38
Noirsoprenoids																				
β-Damascenone	1.70	0.11	3.93	0.00	3.84	0.01	4.70	4.70	3.41	0.05	1.64	0.08	4.04	0.35	2.94	0.09	3.30	0.50	3.19	0.06
3-Hydroxy-βdamascone	0		0		0		0		0		0		0		0		0		0	
Vitispirane	66.76	5.39	67.42	0.07	43.31	8.82	7.65	7.63	144.80	11.97	280.60	15.39	195.69	0.60	468.69	66.48	166.71	3.80	396.33	103.47
TPB	1.41	0.12	1.37	0.10	1.12	0.32	0.32	0.22	1.73	0.02	3.13	0.08	4.92	0.29	6.31	0.99	2.51	0.15	4.45	1.48
TDN	24.53	4.48	30.01	4.45	24.43	9.30	7.91	1.15	42.53	2.69	126.49	19.05	132.53	41.36	259.16	65.69	73.18	1.99	142.35	37.47
3-Oxo-α-ionol	1.70	0.08	2.15	0.05	2.74	0.04	1.92	0.09	2.08	0.08	1.95	0.03	2.18	0.01	2.68	0.03	2.02	0.03	2.22	0.01
Benzenoids																				
Furfural	3.49	0.01	4.34	1.27	2.51	0.05	5.14	0.28	2.21	0.39	80.21	7.33	163.84	0.08	119.19	18.52	141.13	3.04	78.65	1.91
Benzaldehyde	15.47	0.17	17.35	1.52	15.89	0.94	15.06	0.21	15.67	0.56	16.62	0.37	15.88	0.41	15.50	0.53	16.52	1.27	17.08	0.92
Benzyl alcohol	11.39	2.06	44.81	19.04	23.38	3.26	24.85	7.83	10.35	1.14	18.08	1.74	17.28	0.88	40.85	9.20	20.80	7.38	15.71	3.38
Vanillin	22.81	3.81	20.97	1.36	25.26	1.98	33.50	3.64	14.93	1.93	18.60	1.91	17.60	0.91	29.28	5.81	21.96	1.98	19.84	0.15
Methyl-vanillate	12.52	0.04	9.98	0.03	15.65	1.31	12.52	0.51	20.51	0.32	13.21	0.15	10.13	0.32	16.08	2.35	13.49	0.47	18.86	0.72
Ethyl-vanillate	62.86	1.92	160.73	13.12	160.75	14.04	117.65	6.96	110.78	1.58	82.09	0.98	137.89	1.81	165.59	49.08	123.93	0.74	124.02	2.75
Methyl salycilate	0.19	0.01	0.24	0.02	0.65	0.05	1.03	1.03	0.36	0.01	0.27	0.03	0.45	0.04	0.63	0.03	0.76	0.06	0.44	0.05
2,6-Dimethoxy-phenol	6.02	0.29	7.88	0.18	5.75	0.67	6.97	0.54	6.39	0.80	12.00	0.23	14.72	0.46	4.47	0.26	18.87	0.51	13.81	0.30
Eugenol	0.47	0.18	0.94	0.09	0.76	0.11	0.88	0.34	0.34	0.00	0.32	0.04	0.57	0.10	0.76	0.21	0.37	0.02	0.51	0.21
Others																				
γ-Nonalactone	19.71	0.18	26.00	4.16	21.02	3.31	13.50	0.50	20.42	0.23	21.84	0.40	21.66	0.41	25.71	6.06	13.64	0.39	19.90	0.22

V1-5 is short for Vineyards 1-5

Appendix 4.3.3. Concentration (µg/L) and standard deviation (± µg/L) of free compounds of T16 and T40 2018 fresh Corvina wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	d,s,	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	135.38	18.36	178.64	0.96	156.02	11.19	148.82	22.01	135.54	26.06	115.00	7.07	135.82	22.25	134.65	3.50	133.85	4.56	130.07	11.78
Isoamyl alcohol	281416.25	3222.35	213995.13	4486.80	295044.85	10071.37	376884.68	45189.22	290375.37	46275.86	158565.79	2202.23	182486.91	7524.96	280070.93	24439.51	339626.03	9417.72	307554.18	15573.57
1-Pentanol	78.02	12.08	78.27	1.15	68.14	9.57	88.70	7.17	64.88	0.42	40.23	25.53	92.18	7.32	95.28	10.44	62.53	2.37	36.61	1.85
Phenylethyl alcohol	15752.02	475.27	12373.72	533.52	18703.79	1958.17	28617.33	5010.77	18605.39	2006.15	14420.86	7254.04	13072.67	545.43	17780.12	921.40	19355.04	206.84	26422.15	708.56
Methionol	353.68	0.11	278.78	19.28	290.98	59.64	441.79	39.57	410.06	31.95	167.41	112.92	366.99	53.06	479.67	27.82	17.04	0.04	402.12	3.00
C_6 alcohols																				
1-Hexanol	977.20	12.20	1443.99	18.12	2104.29	26.10	701.55	45.30	811.89	79.21	780.17	293.79	1493.13	106.55	2250.35	77.36	733.52	29.33	780.20	55.35
trans-3-Hexen-1-ol	5.94	0.04	11.09	0.49	16.01	0.19	4.35	0.22	6.18	0.33	4.78	2.47	12.64	0.45	18.30	1.15	5.98	0.24	6.15	0.78
cis-3-Hexen-1-ol	461.19	1.20	611.20	2.86	555.25	3.59	332.51	5.54	213.27	17.75	263.77	178.85	660.03	28.70	617.06	38.89	372.59	10.08	217.42	17.07
cis-2-Hexen-1-ol	14.26	0.23	14.68	0.06	14.52	0.37	14.41	0.62	17.04	1.90	14.99	0.45	16.80	0.73	18.13	0.18	16.28	0.70	12.97	1.12
Esters																				
Isoamyl acetate	467.55	7.53	579.92	2.04	745.14	141.10	995.15	141.55	387.20	82.07	339.21	18.69	341.50	42.57	571.61	15.87	630.16	28.19	180.54	1.75
2-Phenethyl acetate	26.59	0.34	26.89	0.32	36.31	5.42	66.06	6.20	34.31	1.78	28.84	0.52	26.79	1.18	44.99	8.44	12.63	0.32	28.22	2.64
n-Hexyl acetate	2.97	0.82	4.63	0.16	6.38	2.96	6.25	1.61	2.52	0.65	2.70	0.00	3.23	0.48	70.06	82.18	3.45	0.04	2.67	0.01
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	12.50	0.28	9.74	0.30	20.28	0.42	21.10	1.79	20.15	0.21	31.50	0.71	14.80	0.42	38.25	0.92	38.95	0.64	41.99	0.01
Ethyl-3-methylbutanoate	23.32	4.34	13.39	1.65	53.05	7.25	22.31	1.99	22.03	1.45	42.00	2.83	22.66	0.65	54.45	1.48	32.65	0.78	51.80	0.29
Ethyl fatty acids esters																				
Ethyl butanoate	171.23	19.57	146.26	3.99	255.48	38.01	136.70	23.74	102.22	3.13	191.50	2.12	157.50	2.12	235.50	2.12	156.00	5.66	118.90	7.74
Ethyl hexanoate	349.67	7.34	312.99	1.87	465.88	37.76	333.54	0.83	220.64	26.94	356.90	8.92	304.07	41.71	587.34	53.44	239.50	11.20	194.99	30.33
Ethyl octanoate	160.49	2.35	131.51	0.37	143.51	26.82	96.31	4.63	83.82	5.40	134.38	36.26	75.35	9.79	128.68	1.87	1.67	0.03	54.88	12.19
Ethyl decanoate	15.43	0.10	11.97	0.83	9.85	1.83	16.56	0.00	10.20	0.08	15.95	7.30	10.24	1.51	6.60	0.57	1.64	0.03	4.90	0.16
Ethyl-3-hydroxybutanoate	241.47	1.51	203.42	1.22	207.75	6.96	152.71	19.47	171.93	2.73	122.18	3.08	251.82	2.57	261.00	29.69	187.28	2.41	193.60	38.74
Ethyl lactate	1548.85	25.79	3140.22	157.42	3229.16	179.68	1807.96	34.16	2241.98	223.53	1180.80	97.07	4733.25	329.86	3523.52	138.56	3350.80	113.32	3094.82	441.45
Fatty acids																				
3-Methylbutanoic acid	483.46	11.15	294.55	5.93	396.08	13.48	536.64	27.99	366.02	50.68	507.64	41.71	329.26	32.41	524.19	32.79	28.16	0.32	358.10	45.13
Hexanoic acid	2046.92	77.48	1911.69	5.64	2344.69	62.60	1455.13	139.65	1567.22	211.41	3534.64	758.05	2477.03	122.45	3082.98	161.91	0.21	0.00	1490.14	116.09
Octanoic acid	3536.72	93.26	3368.63	63.92	3601.35	176.47	3222.15	335.54	3021.82	151.71	5675.38	1369.44	4197.61	86.49	4382.32	257.83	3653.75	5.17	2966.19	90.91
Terpenes																				
trans-Linaloloxide																				
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	6.98	0.04	14.65	0.92	14.07	4.02	16.70	0.16	15.32	2.01	3.68	0.20	2.75	0.04	6.52	0.08	15.56	0.52	3.45	0.06
α-Terpineol	1.23	0.11	4.02	0.18	5.60	0.13	3.62	0.70	6.83	0.35	2.17	0.23	4.26	0.01	3.87	0.63	9.37	0.69	6.52	1.55
β-Citronellol	19.53	2.28	15.13	0.98	12.47	3.47	19.47	1.68	5.77	0.09	0.95	0.06	3.62	0.26	4.36	2.66	2.12	0.43	4.08	0.16
Geraniol	7.17	0.67	5.53	1.10	5.93	0.12	5.85	0.90	3.56	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
α-Terpinen																				
1,4-Cineole	0.00	0.00	0.00	0.00	0.11	0.01	0.00	0.00	0.02	0.00	0.13	0.01	0.16	0.01	0.15	0.01	0.10	0.01	0.17	0.02
Limonene	0.41	0.08	0.70	0.20	0.79	0.15	0.63	0.05	0.68	0.10	0.29	0.01	0.37	0.06	0.81	0.01	0.90	0.08	0.38	0.04
1,8-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.01	0.00	0.00	0.21	0.01	0.23	0.01	0.21	0.01	0.36	0.01
p-Cymene	0.17	0.01	0.26	0.01	0.26	0.03	0.21	0.01	0.23	0.04	0.10	0.00	0.15	0.04	0.22	0.00	0.22	0.01	0.48	0.04
Terpinen-4-ol	0.15	0.01	0.30	0.06	0.47	0.02	0.24	0.01	0.53	0.08	0.16	0.02	0.38	0.07	0.38	0.02	0.40	0.13	0.55	0.14
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.49	4.19	3.52	0.79	2.14	0.20	3.76	0.04	10.20	1.00
Noirsoprenoids																				
β-Damascenone	1.69	0.09	1.77	0.04	1.91	0.22	1.76	0.28	1.75	0.20	1.53	0.14	0.79	0.12	1.33	0.26	0.69	0.12	2.04	0.41
3-Hydroxy-βdamascone	0.17	0.02	0.10	0.01	0.11	0.01	0.22	0.03	0.17	0.04	0.32	0.08	0.20	0.01	0.12	0.02	0.00	0.00	0.09	0.01
Vitispirane	1.41	0.22	2.55	0.08	1.70	0.13	1.65	0.06	7.05	1.42	12.13	0.86	9.44	1.31	14.82	0.25	8.54	0.00	32.63	0.01
TPB	0.03	0.01	0.06	0.01	0.32	0.02	0.04	0.01	0.11	0.02	0.40	0.01	0.13	0.01	0.14	0.02	0.05	0.01	0.48	0.08
TDN	0.43	0.03	0.73	0.10	0.60	0.00	0.50	0.02	1.97	0.37	1.56	0.22	1.09	0.19	3.10	0.15	3.06	0.03	12.87	1.75
3-Oxo-α-ionol	0.66	0.01	0.54	0.05	0.61	0.07	0.72	0.06	0.90	0.01	1.99	0.25	2.09	0.13	2.18	0.03	2.17	0.01	1.45	0.29
Benzenoids																				
Furfural	3.93	0.22	3.94	0.09	2.79	0.02	3.74	0.00	4.43	0.88	17.20	16.21	75.33	4.90	60.93	1.32	65.24	0.96	65.56	0.79
Benzaldehyde	6.31	0.06	5.81	0.19	3.27	0.23	2.24	0.30	1.31	0.01	15.77	2.72	13.84	0.01	15.57	2.01	14.12	0.22	2.08	0.11
Benzyl alcohol	133.45	1.85	49.19	1.73	117.86	0.03	72.72	9.82	59.70	1.94	99.06	42.11	76.86	9.86	121.19	2.43	37.93	1.74	90.26	2.12
Vanillin	15.60	1.00	4.43	0.14	3.55	0.67	16.86	2.70	10.63	0.84	15.37	6.92	8.55	1.75	5.37	0.86	9.82	0.42	20.70	1.24
Methyl-vanillate	3.64	0.05	4.73	0.04	5.85	0.28	6.63	1.06	9.29	0.45	11.41	3.48	9.97	1.94	7.42	0.74	28.35	0.12	9.03	0.68
Ethyl-vanillate	67.33	0.97	31.35	0.35	59.89	8.30	80.47	6.27	61.82	1.01	124.96	25.54	96.23	10.41	151.02	7.51	168.76	1.42	109.89	26.42
Methyl salycilate	0.17	0.01	0.35	0.01	0.50	0.57	0.24	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.01	0.00	0.00	1.12	0.11
2,6-Dimethoxy-phenol	7.15	0.28	5.71	0.23	6.80	1.24	7.68	0.79	9.97	0.59	14.25	2.94	6.48	1.39	11.49	1.74	27.14	0.66	14.49	0.86
Eugenol	2.00	0.20	2.57	0.03	0.28	0.04	2.41	0.24	1.33	0.04	0.27	0.02	0.23	0.00	2.18	0.35	2.82	0.03	0.24	0.01
Others																				
γ-Nonalactone	6.36	0.16	6.95	0.85	6.39	0.04	6.25	0.01	6.29	0.00	7.11	0.13	7.68	0.11	6.15	0.35	6.05	0.21	6.10	0.41

V1-5 is short for Vineyards 1-5

Appendix 4.3.4. Concentration (μg/L) and standard deviation (± μg/L) of free compounds of T16 and T40 2018 fresh Corvinone wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	167.26	32.78	221.78	36.46	240.68	22.59	107.44	0.96	131.31	27.15	160.88	1.22	146.24	17.52	178.45	32.46	157.36	1.43	124.09	15.91
Isoamyl alcohol	329724.79	20044.38	260515.91	19961.82	252325.80	26633.28	239046.93	15733.47	252494.14	41272.85	371938.35	34564.60	222708.36	28236.33	222789.41	30127.20	307375.62	654.61	277083.26	15765.04
1-Pentanol	65.79	9.40	125.83	15.67	120.39	17.36	76.67	8.66	117.70	25.03	102.09	12.38	79.23	3.31	121.10	24.01	52.58	2.72	97.75	7.59
Phenylethyl alcohol	24351.37	1442.34	19837.92	2616.24	17368.48	2439.77	16118.39	752.66	14850.55	3238.68	23406.34	1574.24	16045.25	1130.22	13740.57	2575.83	17812.25	848.18	19636.11	1193.73
Methionol	369.86	11.67	437.16	42.92	266.86	10.19	331.47	3.48	320.05	14.56	385.26	62.40	404.99	3.46	320.69	55.30	440.27	0.41	371.19	55.19
C_6 alcohols																				
1-Hexanol	1485.72	19.85	1010.95	121.66	1788.84	47.63	684.30	76.46	1571.42	133.51	1841.61	55.22	1169.40	28.36	2376.34	225.26	832.74	200.46	1476.92	96.19
trans-3-Hexen-1-ol	13.73	0.23	15.80	0.31	27.60	0.39	6.24	0.03	23.46	0.69	18.52	1.07	16.24	0.01	34.41	6.00	7.69	1.44	25.23	1.00
cis-3-Hexen-1-ol	91.44	3.49	42.01	5.87	38.42	2.92	28.03	5.99	37.11	2.70	130.24	17.40	47.38	0.62	38.10	1.69	35.40	1.39	35.99	2.64
cis-2-Hexen-1-ol	15.97	0.80	14.61	0.33	14.88	0.68	13.98	0.06	14.26	1.46	15.33	0.05	10.44	2.39	15.90	0.75	15.19	0.91	15.72	0.16
Esters																				
Isoamyl acetate	492.58	12.14	542.02	80.50	773.71	5.57	568.81	2.01	327.40	22.09	470.33	19.28	260.97	37.75	492.89	72.95	463.37	22.48	193.40	21.95
2-Phenethyl acetate	28.22	0.12	26.93	1.51	23.40	0.89	43.23	3.55	19.55	1.50	26.94	1.38	23.20	1.02	22.43	1.05	37.72	3.41	21.03	0.83
n-Hexyl acetate	4.13	0.64	3.15	1.20	9.04	4.22	3.58	0.53	3.49	0.92	2.63	0.32	0.00	0.00	2.29	0.74	4.31	2.33	1.11	1.57
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	15.25	2.32	13.25	2.20	9.49	0.68	11.42	0.75	16.17	0.64	36.80	0.91	17.45	1.32	12.49	0.87	35.32	3.96	32.55	2.61
Ethyl-3-methylbutanoate	21.07	2.45	13.43	0.88	14.29	0.90	11.90	0.49	19.08	1.11	40.15	4.67	21.93	1.61	16.78	0.63	35.27	2.82	34.66	1.98
Ethyl fatty acids esters																				
Ethyl butanoate	149.08	1.01	143.57	13.25	212.96	20.55	102.56	3.20	125.90	16.40	231.77	26.49	127.52	8.48	194.17	34.03	168.89	3.79	137.72	2.94
Ethyl hexanoate	347.84	0.76	274.65	7.32	470.43	42.18	188.26	4.47	322.23	28.92	463.45	93.76	212.59	4.77	394.81	82.50	153.71	5.25	282.53	16.20
Ethyl octanoate	168.13	9.90	105.91	12.51	163.23	18.17	112.22	22.61	125.49	6.48	71.31	8.10	46.69	3.34	97.29	2.91	32.34	1.27	59.20	2.72
Ethyl decanoate	15.64	2.38	12.22	0.74	16.04	0.42	12.40	0.74	14.34	0.01	3.79	0.28	3.13	0.46	9.03	0.74	2.60	0.00	3.69	0.57
Ethyl-3-hydroxybutanoate	299.70	11.26	190.64	24.32	246.71	13.86	139.92	14.42	198.57	1.80	250.45	20.05	154.45	10.18	202.47	11.55	140.75	23.55	179.84	16.16
Ethyl lactate	2441.12	101.90	2345.96	139.53	2347.38	66.67	1439.55	197.58	1942.08	22.75	4549.86	123.58	3704.69	125.15	4672.92	14.16	3010.30	695.54	2747.17	34.61
Fatty acids																				
3-Methylbutanoic acid	420.54	20.29	286.10	35.84	290.21	28.31	274.75	16.68	292.08	19.28	524.42	159.46	324.67	11.40	286.64	41.52	277.87	3.73	303.18	45.42
Hexanoic acid	2359.39	38.47	1699.84	201.30	2408.12	222.36	929.98	16.77	1568.65	263.93	2661.98	107.03	1869.25	231.12	2600.97	342.97	1036.38	28.83	1921.84	133.68
Octanoic acid	3958.55	25.89	3508.53	263.86	4476.97	341.47	2758.93	347.44	2908.73	147.98	4387.73	352.11	3728.99	245.64	4288.66	318.71	3274.07	411.51	3470.73	38.98
Terpenes																				
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.98	1.40	3.09	0.04	1.39	0.01	0.00	0.00	10.03	0.86
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.21	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	9.875	0.80	4.23	0.51	4.265	0.45	6.22	0.71	8.855	0.76	3.63	0.43	1.745	0.11	2.99	0.17	3.53	0.31	0.685	0.61
α-Terpineol	2.58	0.07	1.34	0.01	1.15	0.08	1.98	0.13	5.22	0.21	5.12	0.91	2.93	0.06	2.57	0.04	4.43	0.28	6.62	0.84
β-Citronellol	13.89	0.14	12.10	0.53	17.49	1.05	17.37	0.35	7.76	0.30	3.12	0.63	4.53	0.51	4.52	0.77	8.40	0.59	5.99	0.42
Geraniol	4.94	0.90	3.71	0.22	5.00	0.13	5.50	1.06	3.39	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
α-Terpinen																				
1,4-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.06	0.01	0.05	0.00	0.00	0.00	0.06	0.00
Limonene	0.38	0.01	0.22	0.01	0.18	0.01	0.31	0.01	0.54	0.01	0.30	0.05	0.19	0.00	0.21	0.00	0.29	0.04	0.30	0.03
1,8-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.08	0.01	0.11	0.02	0.00	0.00	0.25	0.04
p-Cymene	0.16	0.00	0.13	0.01	0.11	0.01	0.11	0.01	0.18	0.00	0.12	0.01	0.13	0.00	0.11	0.00	0.11	0.01	0.10	0.00
Terpinen-4-ol	0.16	0.04	0.20	0.03	0.46	0.07	0.19	0.01	0.26	0.05	0.37	0.06	0.32	0.05	0.49	0.01	0.23	0.03	0.33	0.04
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.02	0.00	0.00	0.00	0.00	7.12	1.00
Noirsoprenoids																				
β-Damascenone	6.71	0.07	2.68	0.01	1.89	0.30	1.24	0.17	3.57	0.24	5.92	1.00	3.01	0.65	2.40	0.23	1.23	0.24	5.55	0.33
3-Hydroxy-βdamascone	0.20	0.01	0.12	0.02	0.07	0.00	0.15	0.00	0.18	0.02	0.32	0.01	0.23	0.03	0.18	0.01	0.28	0.00	0.40	0.04
Vitispirane	4.94	0.32	3.96	0.18	2.98	0.16	3.65	0.05	25.00	1.14	27.53	5.59	25.25	0.05	20.04	0.60	22.64	1.58	93.18	4.12
TPB	0.06	0.00	0.04	0.00	0.04	0.00	0.03	0.00	0.12	0.00	0.22	0.03	0.24	0.00	0.15	0.00	0.13	0.00	0.70	0.09
TDN	0.99	0.05	0.83	0.03	0.57	0.03	0.45	0.00	5.55	0.14	6.87	0.61	7.15	0.17	4.56	0.33	4.15	0.06	47.10	4.80
3-Oxo-α-ionol	0.64	0.08	0.68	0.02	0.72	0.06	0.28	0.04	0.70	0.11	0.72	0.06	0.55	0.06	1.01	0.09	0.42	0.01	1.00	0.19
Benzenoids																				
Furfural	5.84	0.54	4.59	0.57	4.03	0.03	2.28	0.39	4.93	0.29	104.13	8.05	97.66	10.88	178.95	8.25	52.64	10.17	99.94	2.75
Benzaldehyde	1.94	0.01	3.29	0.74	2.81	0.06	0.82	0.07	1.13	0.19	2.26	0.06	4.08	0.56	2.43	0.33	0.68	0.18	1.28	0.21
Benzyl alcohol	69.35	1.85	26.52	9.16	39.06	1.75	10.25	0.81	26.79	3.63	58.14	2.91	31.80	0.84	38.17	6.55	13.82	0.26	31.14	3.22
Vanillin	21.16	2.21	14.04	2.52	7.96	0.52	4.48	0.17	10.31	1.59	17.48	2.86	15.10	2.96	13.63	1.36	7.13	0.81	18.39	1.34
Methyl-vanillate	21.29	0.40	8.58	0.47	10.20	0.62	8.32	0.27	18.58	0.66	22.10	1.40	8.21	1.01	11.35	1.85	9.56	1.07	17.96	0.87
Ethyl-vanillate	93.66	1.29	72.50	7.95	89.41	3.85	57.63	0.08	77.48	12.00	105.96	3.78	57.13	15.68	78.18	7.47	80.89	3.11	116.33	16.24
Methyl salycilate	0.47	0.00	0.54	0.03	0.43	0.07	0.00	0.00	0.50	0.01	0.33	0.06	0.35	0.02	0.17	0.04	0.17	0.00	1.12	0.11
2,6-Dimethoxy-phenol	8.87	0.17	8.18	0.81	7.77	0.50	6.60	0.45	8.61	1.39	13.22	1.05	12.27	2.27	14.65	0.73	14.85	2.10	17.55	3.26
Eugenol	1.39	0.04	0.25	0.00	0.62	0.54	0.24	0.01	0.35	0.03	1.33	0.12	0.58	0.15	0.26	0.01	0.28	0.02	0.85	0.21
Others																				
γ-Nonalactone	7.76	1.05	6.26	0.03	6.40	0.13	6.26	0.02	6.27	0.00	6.65	0.45	7.21	1.16	7.22	1.34	6.34	0.02	6.41	0.04

V1-5 is short for Vineyards 1-5

Appendix 4.3.5. Concentration (μg/L) and standard deviation (± μg/L) of free compounds of T16 and T40 2019 fresh Corvina wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	137.32	5.33	461.62	75.50	169.65	30.82	197.90	20.30	163.88	20.07	156.13	12.91	434.39	69.44	189.13	22.96	132.72	19.63	161.56	7.04
Isoamyl alcohol	228260.93	12947.29	286639.92	24899.12	207255.55	29903.01	233535.83	31962.22	192108.44	10978.82	217458.26	14375.91	250557.33	15320.78	162431.03	8044.53	230300.17	6657.07	163072.25	10949.59
1-Pentanol	55.81	0.42	97.93	9.43	60.99	19.03	49.04	8.85	64.97	3.73	391.43	14.42	468.67	10.54	446.73	39.64	438.30	7.32	497.38	2.69
Phenylethyl alcohol	18168.66	1102.90	18892.42	174.40	14701.96	2734.28	19349.46	1940.39	14077.13	782.90	14709.92	3056.21	12958.44	1895.87	14755.64	2226.72	15514.59	2592.65	10958.20	1123.52
Methionol	467.23	25.70	402.59	3.66	465.22	83.35	512.82	66.12	348.31	21.06	561.67	42.21	886.19	219.85	517.73	18.59	553.35	62.75	364.16	13.63
C_6 alcohols																				
1-Hexanol	946.82	40.26	1464.87	110.46	879.87	14.03	756.44	66.35	1712.49	84.40	907.62	48.28	1352.26	184.99	946.49	183.66	738.49	16.74	1550.51	26.57
trans-3-Hexen-1-ol	7.79	0.35	9.31	1.00	5.75	0.08	5.38	0.71	10.02	0.88	7.98	0.62	10.17	1.03	5.15	0.30	5.11	0.05	9.39	0.42
cis-3-Hexen-1-ol	294.46	10.34	584.49	86.92	237.96	4.95	226.87	14.89	327.82	14.81	279.80	5.68	552.70	117.85	259.66	48.61	218.97	5.44	306.31	2.14
cis-2-Hexen-1-ol	13.72	1.10	14.26	1.43	14.17	1.22	13.52	0.16	14.43	1.24	13.44	0.33	13.91	0.61	13.29	0.72	14.15	0.48	14.11	1.11
Esters																				
Isoamyl acetate	316.45	4.39	301.99	14.25	270.66	23.34	378.24	26.18	262.50	2.26	218.65	5.26	202.71	35.50	143.81	5.08	272.56	24.07	157.96	10.01
2-Phenethyl acetate	28.67	1.33	23.58	0.85	24.85	2.48	27.54	2.10	24.69	0.13	25.45	1.07	23.33	2.35	21.42	1.47	26.30	2.03	20.97	0.00
n-Hexyl acetate	0.14	0.02	0.33	0.00	0.06	0.00	0.08	0.01	0.23	0.00	0.10	0.00	0.29	0.03	0.11	0.00	0.11	0.02	0.35	0.00
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	16.81	0.73	20.09	0.67	21.68	0.76	18.00	0.75	16.80	0.95	22.50	0.59	28.41	2.31	31.01	0.08	25.33	3.52	22.93	0.70
Ethyl-3-methylbutanoate	17.25	3.89	27.23	2.77	29.20	1.23	22.94	0.47	16.79	0.04	26.73	5.03	34.06	3.54	37.05	2.69	26.21	2.31	19.55	0.81
Ethyl fatty acids esters																				
Ethyl butanoate	146.59	7.81	225.52	25.34	204.83	17.62	176.70	7.11	186.93	5.13	131.42	6.28	197.56	36.97	181.56	35.21	162.90	3.95	156.78	5.53
Ethyl hexanoate	252.25	39.92	419.96	9.87	392.82	3.18	226.00	26.48	291.90	8.03	192.03	21.77	337.89	0.67	321.57	12.27	202.52	16.21	257.15	1.53
Ethyl octanoate	90.64	12.74	161.44	16.01	122.63	7.88	62.97	6.35	99.05	8.75	32.04	2.36	71.12	8.74	84.91	6.24	40.64	12.67	55.23	3.44
Ethyl decanoate	10.14	0.13	19.96	0.19	11.50	1.01	8.23	1.08	13.59	1.09	2.96	0.54	7.09	3.60	7.85	1.34	4.11	0.16	4.33	0.21
Ethyl-3-hydroxybutanoate	239.44	15.56	637.13	86.72	386.92	69.95	289.25	33.04	334.79	24.32	228.77	14.58	562.20	63.76	357.47	11.29	262.51	29.01	288.30	8.27
Ethyl lactate	1747.40	126.63	4449.10	371.25	6146.73	1270.89	2284.11	356.83	5055.58	576.82	2634.14	248.71	4209.71	220.81	7701.30	1282.08	3158.17	384.02	5632.74	176.03
Fatty acids																				
3-Methylbutanoic acid	469.33	16.86	418.25	72.80	335.64	39.51	457.39	17.18	252.59	0.66	440.10	25.76	393.22	27.70	323.78	28.74	439.06	11.06	223.49	2.51
Hexanoic acid	2103.92	43.76	2893.94	60.51	2423.87	228.19	1922.22	55.01	2415.73	53.96	2018.25	91.12	2841.45	113.98	2432.04	249.94	1898.43	41.51	2219.42	86.37
Octanoic acid	3898.95	47.64	3982.05	14.43	4226.45	150.45	3925.13	10.59	3945.31	13.56	3932.61	33.61	4134.63	48.90	4278.04	48.07	3898.94	117.20	3783.21	148.08
Terpenes																				
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.35	1.24	0.00	0.00	0.00	0.00
cis-Linaloloxide	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.47	1.43	0.00	0.00	12.68	17.93
Linalool	11.655	1.71	35.5	2.87	32.855	4.76	29.115	2.11	47.255	3.43	5.99	4.98	6.685	0.81	4.115	0.55	15.49	1.71	4.9	0.39
α-Terpineol	2.26	0.09	20.65	1.72	18.99	0.74	8.03	0.30	27.34	0.11	5.95	0.28	26.62	2.32	20.87	0.11	14.14	0.89	30.76	3.53
β-Citronellol	12.57	0.36	12.46	1.22	7.83	0.64	14.08	0.21	7.99	0.27	8.17	0.74	7.54	0.40	5.07	0.10	7.97	0.23	5.22	0.64
Geraniol	3.39	0.54	2.15	0.65	2.61	0.30	3.02	0.62	2.52	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
α-Terpinen	0.04	0.01	0.21	0.01	0.18	0.02	0.13	0.01	0.25	0.01	0.05	0.01	0.11	0.01	0.11	0.00	0.17	0.04	0.12	0.04
1,4-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.01	0.24	0.02	0.08	0.01	0.15	0.01
Limonene	0.20	0.01	1.44	0.23	1.24	0.11	0.77	0.02	1.63	0.28	0.18	0.03	0.74	0.01	0.67	0.01	0.73	0.04	0.92	0.13
1,8-Cineole	0.00	0.00	0.1	0.00	0.15	0.00	0.15	0.00	0.25	0.01	0.00	0.00	0.40	0.01	0.58	0.04	0.22	0.02	0.66	0.04
p-Cymene	0.07	0.00	0.20	0.02	0.27	0.01	0.18	0.00	0.30	0.09	0.08	0.01	0.23	0.00	0.26	0.01	0.22	0.01	0.21	0.02
Terpinen-4-ol	0.00	0.00	0.75	0.02	0.70	0.11	0.41	0.03	0.55	0.05	0.38	0.06	0.85	0.12	1.03	0.01	0.52	0.10	1.02	0.03
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00	17.38	7.09	14.99	3.36	1.00	0.00	21.29	2.08
Noirsoprenoids																				
β-Damascenone	3.53	0.22	4.02	0.40	3.67	0.25	2.85	0.10	3.49	0.76	3.67	0.73	3.91	0.12	3.88	0.02	2.92	0.18	5.80	0.69
3-Hydroxy-βdamascone	0.17	0.01	0.14	0.03	0.10	0.00	0.10	0.01	0.14	0.02	0.15	0.00	0.14	0.03	0.09	0.00	0.11	0.01	0.09	0.01
Vitispirane	2.97	0.14	3.58	0.23	4.66	0.37	1.72	0.14	7.21	0.54	20.65	0.76	17.11	0.88	22.51	0.84	9.81	0.35	32.60	3.55
TPB	0.04	0.02	0.09	0.01	0.11	0.00	0.05	0.01	0.13	0.00	0.09	0.02	0.26	0.02	0.35	0.02	0.16	0.00	0.42	0.02
TDN	0.46	0.01	1.17	0.03	1.50	0.15	0.44	0.01	2.59	0.22	4.39	0.35	8.03	0.18	12.40	0.68	2.67	0.26	16.33	3.14
3-Oxo-α-ionol	1.74	0.08	1.04	0.09	1.24	0.13	1.73	0.18	2.28	0.07	1.73	0.05	0.87	0.06	1.41	0.15	1.83	0.06	2.26	0.09
Benzenoids																				
Furfural	3.36	0.49	3.61	0.45	6.93	1.35	14.75	1.32	7.02	0.23	120.97	1.58	137.45	21.54	115.43	19.64	124.80	9.59	152.20	6.89
Benzaldehyde	1.20	0.15	1.17	0.02	5.67	0.25	10.66	0.64	1.86	0.22	10.24	0.60	4.55	0.19	13.79	1.43	8.27	0.04	4.54	0.16
Benzyl alcohol	160.27	17.28	158.96	23.95	101.39	2.98	162.12	16.31	114.85	0.97	111.24	6.17	134.97	13.23	123.37	9.53	161.38	5.20	86.08	11.80
Vanillin	6.72	0.03	12.05	0.18	7.95	0.71	11.02	0.88	8.02	0.44	12.39	1.04	14.89	0.23	9.28	1.32	9.98	1.73	7.70	0.09
Methyl-vanillate	4.97	0.52	10.52	1.53	9.57	0.49	7.00	0.53	15.70	0.79	5.18	0.90	9.06	0.66	9.84	0.58	7.64	0.84	16.78	0.35
Ethyl-vanillate	155.85	1.50	91.02	9.39	100.54	5.94	109.55	0.51	132.32	4.43	189.63	16.08	113.80	9.53	101.39	16.82	114.00	9.98	145.45	11.18
Methyl salycilate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.01	0.21	0.01	0.00	0.00	0.19	0.01	0.50	0.01	0.00	0.00
2,6-Dimethoxy-phenol	7.32	0.04	8.82	1.27	7.92	0.77	6.55	0.45	7.61	0.22	11.02	0.05	13.94	1.71	12.36	0.11	10.62	0.42	9.46	0.95
Eugenol	0.25	0.00	6.58	0.02	2.05	2.55	5.92	0.06	5.11	0.16	2.20	2.74	3.43	0.24	2.09	0.12	3.33	0.05	5.07	0.23
Others																				
γ-Nonalactone	7.11	0.15	6.93	0.93	12.48	0.81	12.21	0.35	7.88	0.71	6.17	0.23	6.41	0.01	11.96	0.62	11.41	0.37	7.87	0.69

V1-5 is short for Vineyards 1-5

Appendix 4.3.6. Concentration (μg/L) and standard deviation (± μg/L) of free compounds of T16 and T40 2019 fresh Corvinone wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	144.36	8.61	93.84	5.42	147.29	23.09	108.74	12.35	178.49	1.39	172.80	4.36	353.97	92.53	153.10	17.37	135.25	15.53	186.14	12,14
Isoamyl alcohol	203165.59	391.32	265871.72	109881.53	186936.89	16163.96	232247.30	6970.57	192081.55	494.97	202827.06	10639.97	271359.03	53381.75	193046.40	919.24	224550.13	25691.81	195433.63	4059,94
1-Pentanol	188.92	37.55	236.19	18.12	309.47	29.92	365.87	51.38	387.27	3.51	265.71	25.43	415.65	12.61	490.18	73.64	480.15	8.34	492.29	1,15
Phenylethyl alcohol	17520.07	395.77	19418.65	3678.85	16098.92	122.92	16551.54	2057.09	11652.31	1593.28	19324.09	1811.18	18099.29	276.07	10812.15	1953.21	15354.82	2345.47	13545.35	1438,74
Methionol	277.67	22.37	1082.24	961.80	565.57	67.37	736.31	112.29	376.17	14.98	349.99	26.59	1394.54	388.08	625.47	72.70	770.36	89.58	410.66	45,21
C_6 alcohols																				
1-Hexanol	821.59	7.40	2336.29	417.06	1257.59	80.26	1360.36	37.37	2655.10	78.57	839.22	32.32	2355.70	172.13	1254.43	128.14	1320.05	99.12	2823.62	60,70
trans-3-Hexen-1-ol	10.23	0.60	30.64	2.35	16.84	0.86	17.62	1.20	48.11	1.13	9.81	0.90	33.42	5.98	17.46	1.90	16.32	0.04	48.90	1,43
cis-3-Hexen-1-ol	17.14	1.41	68.26	4.67	24.83	2.47	42.99	1.30	47.19	0.17	20.16	0.31	69.64	12.22	28.47	2.27	43.84	4.81	48.22	1,25
cis-2-Hexen-1-ol	10.54	1.55	14.43	1.24	14.88	0.33	5.24	0.11	13.91	0.34	14.46	0.35	15.36	1.87	14.54	0.37	14.54	1.16	15.40	1,07
Esters																				
Isoamyl acetate	336.02	24.06	293.25	26.18	297.27	32.86	444.62	24.08	353.55	9.60	251.60	6.60	200.86	7.37	223.81	28.20	287.68	21.76	225.77	3,82
2-Phenethyl acetate	33.66	2.96	26.20	1.40	22.23	1.62	39.45	2.48	27.27	0.16	28.74	1.24	24.30	1.18	20.90	1.73	30.32	3.55	22.74	0,07
n-Hexyl acetate	0.19	0.04	1.67	0.04	2.04	0.05	0.13	0.01	3.31	0.09	0.16	0.00	0.30	0.00	0.15	0.02	0.19	0.00	0.27	0,00
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	28.77	2.55	22.95	1.94	11.04	1.05	17.74	0.91	13.77	0.76	49.09	0.33	37.69	2.27	16.87	1.61	28.13	1.89	21.80	0,85
Ethyl-3-methylbutanoate	26.44	0.94	27.97	3.70	14.59	0.21	22.58	4.14	19.20	0.53	46.41	2.24	37.77	1.09	23.11	3.11	32.13	0.43	28.86	4,15
Ethyl fatty acids esters																				
Ethyl butanoate	149.29	4.33	157.39	29.58	168.47	4.02	144.60	2.32	185.53	5.21	165.97	3.75	166.33	8.74	169.12	5.22	150.88	6.92	191.56	3,89
Ethyl hexanoate	195.40	30.04	313.56	2.18	331.52	27.46	288.10	52.42	319.35	8.58	220.72	0.46	297.95	14.31	255.15	33.74	231.09	47.26	296.88	4,60
Ethyl octanoate	48.70	9.49	125.31	12.32	141.46	11.87	141.50	11.85	107.16	5.88	30.90	0.30	65.51	11.02	72.21	7.76	56.44	4.40	54.34	1,05
Ethyl decanoate	5.87	0.82	17.42	1.05	18.36	1.82	19.98	1.07	16.79	0.36	7.22	0.26	9.94	0.83	9.65	0.37	6.60	0.77	5.61	0,48
Ethyl-3-hydroxybutanoate	221.82	15.29	231.63	7.21	325.13	11.88	320.87	29.20	363.60	18.56	224.55	20.50	483.96	63.65	318.05	39.04	301.16	30.41	350.73	18,45
Ethyl lactate	1973.81	218.81	1837.55	194.53	3844.44	718.33	3275.35	635.01	4573.69	209.11	2722.17	235.63	4237.78	166.27	5231.49	854.09	4380.87	660.97	5990.09	399,93
Fatty acids																				
3-Methylbutanoic acid	357.60	2.78	444.35	11.55	308.65	3.96	411.31	5.79	246.66	7.14	364.69	9.62	480.71	116.94	306.62	18.58	392.51	13.28	244.72	0,78
Hexanoic acid	1674.51	37.28	2277.57	154.85	2351.89	91.08	2239.84	57.61	2393.97	63.78	1725.05	49.98	2394.23	32.03	2334.35	143.04	2194.33	95.30	2488.35	88,28
Octanoic acid	3460.35	94.24	3687.13	16.81	4009.84	90.57	4223.12	9.40	3821.81	128.13	3579.78	22.55	3836.60	47.28	4090.66	2.74	4237.69	3.80	3918.01	95,84
Terpenes																				
trans-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	1.17	0.00	0,00
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26	1.78	0.00	0,00
Linalool	19	2.01	13.395	1.61	17.56	1.21	17.283315	2.09	25.05	3.43	3.835	0.31	5.165	0.45	5.245	0.21	4.54	0.54	2.59	0,13
α-Terpineol	8.40	0.46	6.56	0.36	5.77	0.25	5.98	0.18	15.64	2.58	11.49	0.49	7.43	0.21	9.16	0.32	10.11	0.78	13.91	0,16
β-Citronellol	7.88	0.02	8.50	0.88	9.16	0.44	7.14	0.25	10.44	1.43	4.09	0.13	3.62	0.10	5.13	0.18	4.37	0.40	5.15	0,28
Geraniol	1.53	0.09	2.69	0.01	1.27	0.14	0.36	0.02	2.46	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0,00
α-Terpinen	0.16	0.01	0.10	0.01	0.07	0.01	0.08	0.00	0.12	0.01	0.07	0.01	0.22	0.01	0.05	0.01	0.16	0.01	0.07	0,01
1,4-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0,00
Limonene	0.62	0.00	0.39	0.03	0.42	0.01	0.51	0.02	0.87	0.09	0.42	0.05	0.75	0.01	0.30	0.06	0.37	0.01	0.47	0,00
1,8-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.02	0.15	0.01	0.14	0.02	0.14	0.04	0.32	0,04
p-Cymene	0.17	0.01	0.10	0.01	0.10	0.01	0.00	0.00	0.18	0.01	0.17	0.02	0.07	0.01	0.09	0.02	0.09	0.00	0.11	0,01
Terpinen-4-ol	0.24	0.01	0.22	0.04	0.27	0.01	0.19	0.01	0.32	0.04	0.45	0.09	0.39	0.04	0.25	0.06	0.29	0.04	0.45	0,08
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.05	0.11	3.66	0.08	1.13	0.23	2.28	0.00	7.61	0,61
Noirsoprenoids																				
β-Damascenone	2.60	0.26	3.77	0.23	5.88	0.17	5.47	0.24	5.27	0.37	2.70	0.44	4.27	0.30	5.52	0.47	5.71	0.47	5.61	0,54
3-Hydroxy-βdamascone	0.11	0.01	0.08	0.01	0.13	0.01	0.09	0.00	0.11	0.01	0.05	0.00	0.09	0.01	0.16	0.03	0.07	0.01	0.12	0,01
Vitispirane	9.80	1.19	9.06	1.35	4.99	0.15	6.77	0.16	13.80	0.42	51.74	9.28	58.66	5.16	35.58	3.28	43.56	0.22	69.35	9,99
TPB	0.06	0.00	0.07	0.00	0.06	0.00	0.05	0.00	0.11	0.02	0.16	0.02	0.22	0.03	0.20	0.03	0.23	0.05	0.31	0,05
TDN	1.15	0.02	1.68	0.17	1.16	0.10	1.55	0.06	2.85	0.09	9.67	1.68	15.30	1.42	12.61	0.68	13.89	0.82	22.39	4,38
3-Oxo-α-ionol	1.02	0.00	0.84	0.06	1.90	0.30	1.07	0.14	2.14	0.20	0.72	0.14	0.73	0.10	1.28	0.01	1.29	0.01	2.08	0,04
Benzenoids																				
Furfural	15.85	0.96	7.19	0.27	21.11	0.21	34.41	4.36	6.44	0.07	67.39	1.46	183.15	32.82	238.92	19.64	144.57	5.27	163.63	12,99
Benzaldehyde	0.89	0.05	0.91	0.06	8.27	1.62	0.98	0.03	1.43	0.28	1.06	0.06	1.64	0.23	8.73	1.02	1.25	0.01	2.79	0,46
Benzyl alcohol	40.32	2.40	44.68	4.43	44.08	3.93	33.76	0.86	54.32	0.01	58.71	0.91	57.65	1.34	44.91	0.68	37.71	1.01	67.90	6,58
Vanillin	5.84	0.21	9.25	0.41	13.41	2.69	5.81	1.17	8.21	0.36	10.79	1.17	13.22	1.17	17.00	1.10	10.92	0.33	14.12	0,09
Methyl-vanillate	18.51	0.62	18.76	2.87	18.61	0.33	12.65	0.78	26.85	1.51	18.35	0.35	17.03	0.37	20.02	0.92	12.69	2.10	29.27	3,28
Ethyl-vanillate	124.42	1.88	122.48	2.21	316.83	29.24	72.22	6.10	141.23	6.83	126.95	1.33	126.43	10.00	307.30	13.94	81.60	16.22	141.62	1,68
Methyl salycilate	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.01	0.24	0.05	0.14	0.05	0.20	0.00	0.69	0.04	0.00	0.00	0.15	0,21
2,6-Dimethoxy-phenol	9.65	1.00	9.20	0.74	8.81	0.09	8.35	1.11	8.01	0.04	17.74	0.69	17.82	1.41	16.21	0.52	12.52	0.83	12.91	0,71
Eugenol	0.00	0.00	1.15	0.21	2.00	0.06	0.77	0.06	1.15	0.11	1.33	0.01	1.33	0.36	2.03	0.16	0.26	0.05	1.21	0,07
Others																				
γ-Nonalactone	7.31	0.07	6.42	0.16	11.29	0.19	8.26	0.52	8.40	1.03	6.83	0.66	6.30	0.02	11.00	0.38	8.75	0.24	8.32	0,78

V1-5 is short for Vineyards 1-5

Appendix 4.3.7 Concentration (µg/L) and standard deviation (± µg/L) of free compounds of T16 and T40 2017 withered Corvina wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd.	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	120.36	9.64	203.75	4.26	152.70	8.53	127.48	2.58	140.88	10.86	111.44	6.21	189.24	8.22	144.19	15.96	130.70	4.82	142.12	16.93
Isoamyl alcohol	185430.40	16634.02	205851.31	16889.73	200605.17	2774.85	223325.08	6259.59	220399.41	25553.57	184042.60	11700.22	183068.47	3729.33	193202.94	12847.67	193905.27	5100.81	191966.48	23121.32
1-Pentanol	0.74	0.11	54.31	3.03	45.76	3.01	53.80	6.35	45.10	4.88	55.19	0.80	47.23	4.29	35.93	0.48	46.16	7.19	46.30	1.82
Phenylethyl alcohol	24191.32	1986.96	14325.39	1086.28	20927.96	178.66	27038.08	2165.56	18019.18	1882.06	24633.42	1480.81	12734.72	826.73	20158.99	679.79	21571.08	667.90	14283.33	2030.18
Methionol	106.84	4.79	433.45	12.24	279.27	7.66	224.42	4.53	334.48	10.41	127.22	17.35	393.05	20.42	287.88	17.94	235.56	11.06	314.47	14.20
C_6 alcohols																				
1-Hexanol	2033.90	127.03	1439.21	82.63	1584.30	56.88	2666.28	249.11	1813.18	88.02	2063.89	98.66	1371.87	28.85	1637.48	90.04	2462.41	57.30	1592.58	173.27
trans-3-Hexen-1-ol	15.36	0.04	10.13	0.62	11.90	0.65	23.18	1.47	12.49	1.14	14.84	0.71	9.07	1.07	12.66	0.57	20.10	2.21	10.96	0.92
cis-3-Hexen-1-ol	271.00	14.76	113.17	5.40	100.15	2.72	75.24	2.35	155.97	16.77	271.30	22.83	107.88	3.76	99.57	4.37	60.13	0.77	134.47	6.82
cis-2-Hexen-1-ol	5.14	0.81	4.93	0.22	4.07	0.24	8.78	0.75	5.89	0.64	5.22	0.59	3.19	0.23	4.70	0.84	6.80	0.74	3.10	0.45
Esters																				
Isoamyl acetate	223.82	18.22	123.68	8.94	208.61	1.92	251.35	14.17	195.06	11.65	242.39	15.17	92.59	4.64	156.56	8.73	191.02	5.09	110.82	15.72
2-Phenethyl acetate	28.05	1.53	16.68	0.51	26.05	0.62	27.10	0.78	17.71	1.00	28.77	0.37	16.01	0.30	20.72	2.46	22.06	3.48	17.07	0.34
n-Hexyl acetate	0.35	0.00	0.26	0.19	0.07	0.01	0.20	0.01	0.26	0.04	1.52	0.30	0.23	0.02	0.20	0.02	0.20	0.00	0.30	0.00
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	32.79	0.65	11.48	0.78	32.49	0.43	20.77	2.47	19.31	1.38	60.42	3.84	19.62	0.70	59.82	3.43	35.15	0.42	29.34	2.74
Ethyl-3-methylbutanoate	33.92	0.47	18.96	3.38	43.82	0.04	26.83	1.97	33.57	2.17	59.93	2.52	33.75	0.83	74.21	0.20	47.12	2.54	46.71	0.77
Ethyl fatty acids esters																				
Ethyl butanoate	131.06	2.34	154.36	8.27	158.65	16.22	181.30	10.02	200.14	16.76	157.16	25.92	166.85	9.40	186.51	11.11	188.90	0.83	188.31	5.56
Ethyl hexanoate	198.07	18.81	251.70	13.22	234.46	5.50	338.86	33.67	299.00	19.95	217.11	4.62	191.28	0.28	271.98	12.90	336.51	2.64	271.25	21.29
Ethyl octanoate	53.96	3.92	95.50	1.52	57.24	5.56	108.17	4.62	95.82	6.75	32.66	0.49	34.17	2.04	50.18	0.59	57.28	1.05	48.30	3.21
Ethyl decanoate	15.76	2.16	11.71	0.70	6.91	1.33	14.11	1.12	10.37	1.95	4.20	0.35	2.46	0.24	2.91	0.04	2.46	0.06	2.82	0.11
Ethyl-3-hydroxybutanoate	50.57	0.72	147.43	1.83	103.94	1.51	92.11	4.21	168.33	10.97	57.45	5.14	118.69	14.70	97.84	10.84	77.89	3.02	128.87	20.30
Ethyl lactate	1990.12	80.55	2831.28	61.30	2698.75	19.23	1330.46	6.81	2480.74	77.82	2075.30	156.18	3369.38	139.62	2931.04	254.98	1722.06	44.44	2686.21	144.30
Fatty acids																				
3-Methylbutanoic acid	331.38	20.66	350.11	12.79	330.38	11.02	388.70	16.88	300.49	18.03	315.98	12.14	280.21	32.72	271.65	11.71	307.28	18.98	228.09	23.80
Hexanoic acid	1197.02	95.69	1626.28	69.93	1468.92	23.74	2444.10	210.67	2123.03	118.45	1220.31	3.61	1524.76	80.12	1481.44	29.79	2201.33	74.93	1805.00	72.47
Octanoic acid	2458.31	82.90	2447.52	40.97	2645.88	28.31	3525.67	132.61	3097.64	77.09	2506.94	16.08	2636.26	34.15	2701.17	25.63	3472.14	66.55	2994.06	173.33
Terpenes																				
trans-Linaloloxide	0.95	0.03	1.43	0.17	0.62	#DIV/0!	0.00	0.00	0.00	0.00	20.56	0.83	12.83	1.40	11.37	1.33	1.43	0.01	22.34	3.25
cis-Linaloloxide	1.71	0.06	2.69	0.45	2.01	0.20	0.84	0.61	3.14	0.16	14.84	0.29	9.68	0.11	10.20	1.54	1.72	0.10	17.20	1.29
cis-Linaloloxide																				
Linalool	14.20	0.34	17.47	1.14	9.64	0.18	10.36	0.25	19.02	0.36	4.38	0.74	5.47	0.44	2.14	0.19	5.05	0.13	2.02	0.04
α-Terpineol	5.27	0.23	9.49	1.10	4.89	0.08	3.60	0.22	11.46	0.75	8.55	0.51	12.47	0.83	6.15	0.04	6.11	0.28	15.20	0.72
β-Citronellol	7.12	0.25	8.83	0.71	4.74	0.05	5.94	0.23	4.37	0.12	3.74	0.18	3.68	0.23	2.37	0.22	3.48	0.11	2.77	0.19
Geraniol	2.58	0.07	6.08	0.64	2.79	0.93	3.40	0.13	2.63	0.12	0.05	0.01	0.11	0.01	0.06	0.01	0.06	0.01	0.07	0.08
α-Terpinen																				
1,4-Cineole	0		0		0		0		0		0.10	0.01	0.13	0.00	0		0.11	0.01	0.21	0.01
Limonene	0.54	0.00	0.84	0.06	0.51	0.00	0.42	0.01	1.19	0.04	0.47	0.05	0.65	0.08	0.36	0.01	0.41	0.01	0.76	0.06
1,8-Cineole	0.08	0.00	0.00	0.00	0.08	0.01	0.08	0.01	0.11	0.01	0.15	0.01	0.20	0.00	0.21	0.00	0.13	0.01	0.37	0.02
p-Cymene	0.22	0.01	0.17	0.01	0.18	0.00	0.11	0.01	0.21	0.01	0.26	0.04	0.14	0.01	0.18	0.01	0.12	0.01	0.17	0.01
Terpinen-4-ol																				
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.66	0.30	4.50	0.18	3.54	0.37	0.51	0.01	8.18	1.65
Noirsoprenoids																				
β-Damascenone	1.50	0.04	3.64	0.38	2.23	0.02	2.25	0.08	2.45	0.06	1.65	0.06	2.75	0.27	2.69	0.02	2.63	0.16	3.13	0.39
3-Hydroxy-βdamascone	0.23	0.03	0.31	0.03	0.17	0.00	0.16	0.01	0.35	0.01	0.31	0.02	0.22	0.00	0.20	0.01	0.16	0.01	0.39	0.04
Vitispirane	8.59	0.27	3.66	0.37	9.86	0.65	9.10	0.25	8.42	0.03	10.13	2.63	2.90	0.58	7.58	0.05	8.68	0.44	6.67	1.06
TPB	0.12	0.01	0.11	0.00	0.19	0.03	0.11	0.03	0.19	0.03	1.46	0.06	1.85	1.12	3.26	0.12	1.68	0.12	3.97	0.62
TDN	1.57	0.07	1.48	0.12	3.48	0.27	1.75	0.03	3.40	0.09	28.76	4.06	26.10	2.88	66.07	1.01	38.38	0.13	65.80	4.66
3-Oxo-α-ionol	3.91	0.11	4.59	0.42	2.88	0.05	3.37	0.49	3.56	0.10	3.54	0.48	4.14	0.20	3.15	0.43	3.25	0.39	3.21	0.23
Benzenoids																				
Furfural	11.03	1.20	15.75	0.38	9.98	0.37	9.13	0.98	13.40	0.75	62.84	1.01	275.66	0.31	90.19	4.20	110.19	5.53	130.59	6.95
Benzaldehyde	21.14	0.70	16.12	0.33	15.22	1.37	15.45	0.18	17.04	0.67	19.59	0.33	24.08	0.14	16.21	0.04	15.03	0.07	15.96	0.35
Benzyl alcohol	118.35	3.87	169.26	26.04	91.77	4.95	101.81	2.12	134.94	21.13	117.41	8.14	137.27	15.64	75.13	1.77	73.05	1.66	85.94	11.05
Vanillin	10.02	1.20	7.45	0.14	5.04	0.41	5.47	0.88	2.65	0.42	10.79	0.69	8.68	0.37	4.63	0.34	4.85	0.82	10.96	0.89
Methyl-vanillate	6.49	1.23	3.31	0.39	3.49	0.21	4.58	0.13	4.73	0.51	5.60	0.94	3.47	0.67	3.47	0.12	6.19	0.69	5.45	0.44
Ethyl-vanillate	247.11	21.69	177.47	4.77	158.34	4.54	216.55	14.52	202.99	11.39	264.51	16.78	151.43	17.40	186.28	5.62	210.66	16.42	186.92	10.42
Methyl salycilate	0.22	0.00	0.11	0.01	0.17	0.01	0.39	0.02	0.26	0.00	0.56	0.06	0.16	0.03	0.38	0.02	0.47	0.03	0.33	0.03
2,6-Dimethoxy-phenol	9.84	0.27	7.87	1.03	6.62	0.04	10.05	0.74	8.24	0.86	12.95	0.16	10.31	0.48	7.43	0.13	13.30	0.86	9.74	0.93
Eugenol	7.11	0.704141	11.09	1.097766	4.87	0.481776	5.60	0.554132	4.79	0.473991	9.34	0.792264	17.41	1.477496	12.33	1.04632	17.06	1.44796	12.10	1.026546
Others																				
γ-Nonalactone	6.28	0.06	11.67	0.56	15.36	0.15	10.19	2.16	12.15	1.42	6.26	0.18	10.67	0.04	16.36	0.26	9.90	1.52	11.71	1.36

V1-5 is short for Vineyards 1-5

Appendix 4.3.8. Concentration (μg/L) and standard deviation (± μg/L) of free compounds of T16 and T40 2017 withered Corvinone wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	84.05	3.95	213.29	6.49	95.65	134.65	138.52	4.63	122.82	3.30	86.19	9.92	195.11	0.69	209.65	17.27	123.63	11.39	122.67	0.11
Isoamyl alcohol	213621.51	15568.07	222282.77	13066.59	224781.52	6920.01	230046.11	39.17	203321.34	5389.16	199877.69	4870.25	203246.65	2726.05	227170.94	13596.65	216053.12	16739.08	201820.66	5632.53
1-Pentanol	71.09	1.00	107.80	2.35	114.62	3.89	71.25	2.95	96.85	6.71	58.95	3.85	93.77	0.42	117.91	0.19	57.16	2.56	86.25	2.84
Phenylethyl alcohol	25356.95	1192.57	20015.59	881.48	21651.21	707.11	28787.67	437.40	18535.99	969.67	21575.66	298.47	19054.19	346.22	22312.03	598.34	27843.70	1736.19	18913.75	602.83
Methionol	424.56	33.74	498.84	8.14	8.81	12.46	246.28	0.82	299.36	4.43	402.79	43.11	531.39	6.87	491.95	11.49	239.33	17.68	363.61	2.65
C_6 alcohols																				
1-Hexanol	2292.66	6.87	2164.00	24.44	2513.73	21.55	2751.26	71.72	2934.81	46.22	2169.86	#DIV/0!	2012.68	10.53	2494.02	132.72	2505.69	109.36	2841.96	20.72
trans-3-Hexen-1-ol	17.30	0.04	16.16	0.26	22.69	1.00	22.07	1.09	29.87	0.12	16.51	0.89	15.55	0.68	22.85	1.10	21.89	1.28	29.08	0.01
cis-3-Hexen-1-ol	47.36	0.40	39.94	0.05	34.86	1.36	36.04	0.11	38.61	0.96	44.72	2.98	38.76	0.16	34.87	1.06	34.04	2.57	38.77	4.00
cis-2-Hexen-1-ol	6.79	0.86	4.18	0.33	16.39	0.13	17.37	0.78	7.62	1.17	6.86	0.11	5.56	0.07	8.09	0.01	16.86	0.22	10.73	0.98
Esters																				
Isoamyl acetate	118.31	0.17	154.50	8.67	106.82	1.80	223.93	13.34	127.89	1.78	93.58	0.33	107.74	0.40	88.75	2.04	184.47	12.16	94.36	0.60
2-Phenethyl acetate	20.32	1.18	19.80	0.01	17.84	1.53	28.96	3.20	18.40	0.01	19.84	0.30	17.44	0.65	18.06	0.18	26.22	0.90	17.47	0.27
n-Hexyl acetate	0.08	0.01	0.27	0.03	1.56	1.75	0.24	0.00	0.06	0.00	0.11	0.06	0.22	0.00	3.86	0.52	0.13	0.01	0.21	0.02
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	25.95	0.06	17.59	0.97	15.63	0.55	25.95	1.00	21.34	0.22	44.28	0.21	27.59	0.75	26.68	0.04	45.34	4.28	36.84	0.82
Ethyl-3-methylbutanoate	25.48	3.96	24.54	3.60	19.59	0.59	28.32	0.47	33.06	2.62	47.10	3.90	41.97	1.90	39.26	3.13	55.66	4.02	56.47	6.45
Ethyl fatty acids esters																				
Ethyl butanoate	131.44	0.54	181.60	10.76	144.08	5.34	141.36	4.48	181.35	20.90	148.46	2.69	182.99	0.81	162.35	9.21	163.67	14.66	206.30	6.68
Ethyl hexanoate	218.52	1.49	364.69	2.24	268.84	4.20	274.35	28.72	345.55	8.68	224.62	2.60	276.67	1.51	231.22	5.28	280.00	25.13	336.52	2.46
Ethyl octanoate	68.71	1.91	134.89	5.65	91.84	2.94	86.01	10.52	120.32	3.07	40.01	2.67	55.09	0.28	39.89	0.31	45.92	0.83	68.92	0.32
Ethyl decanoate	5.20	0.05	12.31	0.57	11.24	0.48	9.82	0.91	12.03	0.35	2.50	0.30	3.54	0.02	3.25	0.37	3.09	0.12	3.69	0.40
Ethyl-3-hydroxybutanoate	117.37	1.93	161.02	2.47	151.45	2.01	72.38	4.86	175.68	0.71	92.83	8.20	147.34	9.16	136.33	2.94	65.62	6.24	165.33	1.44
Ethyl lactate	2842.14	27.17	2307.27	4.88	1507.07	23.71	1264.74	18.99	2383.35	64.69	3599.56	165.94	2723.80	18.13	2111.29	62.49	1391.11	118.80	2752.00	15.05
Fatty acids																				
3-Methylbutanoic acid	373.89	14.61	367.38	5.35	425.29	18.31	442.80	12.25	311.09	2.90	303.22	17.78	337.35	0.42	432.88	1.68	413.78	32.94	290.33	1.43
Hexanoic acid	1889.20	107.57	2040.04	5.96	1913.73	52.91	1984.42	101.22	2271.18	37.67	1735.01	3.59	2059.37	0.33	1988.98	5.80	1876.27	115.86	2183.59	0.92
Octanoic acid	2320.76	602.09	2978.22	2.49	2698.00	35.91	2829.07	36.52	3234.43	36.47	2936.10	5.49	3383.12	13.96	3059.53	12.64	3048.90	97.26	3349.56	14.31
Terpenes																				
trans-Linaloloxide	0.35	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	1.24	0.05	4.48	0.13	3.82	0.25	4.28	0.55	7.05	5.59
cis-Linaloloxide	0.07	0.01	0.29	0.01	0.52	0.09	0.11	0.00	1.04	0.05	4.23	0.33	4.61	0.10	2.40	0.00	2.61	0.24	4.02	0.46
Linalool	17.44	0.37	10.91	0.69	9.64	0.40	9.20	0.15	14.38	0.46	2.15	0.20	2.54	0.23	4.23	0.38	2.54	0.28	5.10	0.23
α-Terpineol	5.15	0.01	3.07	0.11	1.86	0.08	2.23	0.06	7.79	0.00	7.67	0.06	4.38	0.15	4.15	0.04	4.89	0.06	8.66	0.69
β-Citronellol	3.96	0.13	6.59	0.88	5.63	0.18	4.61	0.12	3.74	0.02	1.36	0.21	2.89	0.22	2.93	0.21	2.33	0.03	2.23	0.01
Geraniol	2.75	0.21	3.12	0.06	3.16	0.19	1.22	0.03	2.18	0.02	0.02	0.00	0.10	0.01	0.03	0.00	0.02	0.01	0.03	0.00
α-Terpinen																				
1,4-Cineole	0		0		0		0		0.01	0.00	0.11	0.00	0.05	0.01	0		0.05	0.01	0.10	0.01
Limonene	0.31	0.02	0.23	0.01	0.18	0.01	0.25	0.01	0.55	0.01	0.38	0.01	0.23	0.01	0.24	0.01	0.31	0.00	0.42	0.04
1,8-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.07	0.00	0.18	0.01	0.11	0.01	0.09	0.00	0.12	0.01	0.22	0.01
p-Cymene	0.07	0.01	0.06	0.01	0.05	0.00	0.06	0.00	0.09	0.00	0.08	0.01	0.06	0.00	0.05	0.00	0.07	0.00	0.08	0.01
Terpinen-4-ol																				
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.30	0.13	2.12	0.03	1.04	0.06	1.20	0.13	6.61	0.13
Noisoprenoids																				
β-Damascenone	2.03	0.06	5.26	0.67	5.62	0.49	2.36	0.04	2.43	0.14	2.56	0.06	4.27	0.18	5.91	0.08	2.74	0.04	3.36	0.25
3-Hydroxy-βdamascone	0.08	0.01	0.18	0.01	0.32	0.02	0.21	0.03	0.20	0.01	0.12	0.02	0.20	0.00	0.44	0.04	0.21	0.00	0.41	0.01
Vitispirane	5.48	0.11	8.28	0.96	4.18	0.59	3.62	5.12	19.99	0.64	7.69	0.37	9.48	0.19	7.08	0.11	10.69	0.28	19.31	1.55
TPB	0.04	0.00	0.11	0.00	0.08	0.00	0.08	0.00	0.13	0.01	1.15	0.12	2.03	0.12	2.12	0.00	1.41	0.00	2.38	0.37
TDN	0.70	0.03	1.65	0.08	0.91	0.09	1.18	0.01	3.96	0.18	29.38	0.25	48.88	1.39	38.73	0.63	44.52	0.76	112.64	14.23
3-Oxo-α-ionol	3.68	0.35	4.68	0.18	4.74	0.19	3.98	0.24	3.67	0.23	2.92	0.02	4.26	0.16	4.80	0.37	4.44	0.25	4.31	0.24
Benzenoids																				
Furfural	9.36	0.58	10.51	0.24	14.62	0.74	4.75	0.40	5.68	2.88	143.94	9.18	196.84	12.99	376.32	0.80	140.57	13.48	97.05	3.44
Benzaldehyde	14.92	0.04	15.01	0.44	14.36	0.71	14.63	0.28	14.85	0.12	15.48	0.01	14.88	0.20	20.52	0.58	19.71	0.52	14.88	0.10
Benzyl alcohol	28.69	3.40	22.04	0.52	42.03	1.80	35.77	1.92	16.70	1.22	18.08	0.93	18.53	1.52	68.59	2.55	58.28	2.97	18.03	2.67
Vanillin	6.75	0.08	4.64	0.03	5.66	4.70	2.88	0.23	2.24	0.16	2.39	0.14	9.49	0.33	8.03	0.06	8.04	0.09	8.76	0.63
Methyl-vanillate	10.83	0.71	8.96	1.65	9.18	0.11	10.09	0.25	22.19	2.21	7.41	0.10	6.35	0.62	6.81	0.93	9.04	0.11	18.46	1.54
Ethyl-vanillate	275.80	17.63	384.98	0.30	378.92	9.60	291.08	41.46	337.76	8.82	218.64	14.47	332.43	2.54	376.01	15.77	313.06	20.98	318.30	8.70
Methyl salycilate	0.43	0.03	0.44	0.04	0.67	0.03	0.59	0.01	0.49	0.01	0.32	0.04	0.35	0.01	0.73	0.01	0.70	0.00	0.59	0.04
2,6-dimethoxy-phenol	12.18	1.51	13.63	0.24	13.39	1.52	13.56	2.23	11.54	1.67	11.33	0.65	13.10	1.36	18.53	0.25	18.18	0.57	16.70	0.78
Eugenol	2.44	0.24129	1.15	0.113349	2.88	0.285138	2.13	0.211011	2.86	0.282631	2.92	0.247721	6.70	0.568573	12.60	1.069494	7.28	0.618081	12.47	
Others																				
γ-Nonalactone	13.10	9.64	10.43	1.90	43.15	2.57	13.06	0.72	13.17	0.07	6.30	0.06	11.98	0.51	45.11	0.33	15.23	0.54	10.05	1.33

V1-5 is short for Vineyards 1-5

Appendix 4.3.9. Concentration (μg/L) and standard deviation (± μg/L) of free compounds of T16 and T40 2018 withered Corvina wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	d.s.	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	126.32	15.42	308.25	37.64	326.57	39.88	202.93	24.78	320.57	39.14	32.74	2.88	205.65	18.07	143.73	12.63	71.99	6.33	128.45	11.29
Isoamyl alcohol	424751.83	34268.49	579487.98	46752.42	462637.73	37325.08	264119.32	21308.84	387768.40	31284.71	350737.53	8065.33	362243.97	8329.92	322247.39	7410.19	316822.90	7285.45	488173.61	11225.72
1-Pentanol	72.56	2.75	138.83	5.25	130.43	4.94	71.35	2.70	123.09	4.66	65.53	1.95	125.64	3.74	137.84	4.10	54.70	1.63	62.10	1.85
Phenylethyl alcohol	36829.11	4529.06	23656.98	2909.22	23465.32	2885.65	31345.40	3854.70	46673.20	5739.64	29760.83	5255.10	18443.64	3256.74	30161.53	5325.86	33728.92	5955.78	23651.91	4176.40
Methionol	478.54	15.22	859.46	27.33	455.67	14.49	189.78	6.03	413.88	13.16	443.93	6.22	765.83	10.72	303.39	4.25	140.11	1.96	274.53	3.84
C_6 alcohols																				
1-Hexanol	1478.10	108.98	1482.05	109.27	1264.95	93.26	1390.84	102.54	1445.35	106.56	1295.48	59.59	1105.80	50.86	1220.83	56.15	1445.23	66.48	1217.21	55.99
trans-3-Hexen-1-ol	14.88	2.25	15.59	2.35	15.11	2.28	15.33	2.31	19.05	2.88	15.10	2.10	10.34	1.44	15.84	2.20	15.18	2.11	16.98	2.36
cis-3-Hexen-1-ol	199.04	3.56	176.12	3.15	99.44	1.78	234.51	4.20	140.96	2.52	199.37	15.33	151.67	11.66	111.70	8.59	151.56	11.65	130.11	10.01
cis-2-Hexen-1-ol	7.18	0.81	23.92	2.70	0.70	0.08	27.51	3.11	22.98	2.60	20.33	0.98	20.95	1.01	21.65	1.04	13.23	0.64	21.54	1.04
Esters																				
Isoamyl acetate	136.78	20.80	363.50	55.28	409.98	62.35	483.30	73.50	404.93	61.58	112.45	8.58	199.91	15.25	402.05	30.66	156.26	11.92	158.95	12.12
2-Phenethyl acetate	19.17	2.04	17.97	1.91	25.55	2.72	35.75	3.81	30.15	3.21	18.62	0.40	18.78	0.41	25.07	0.54	17.47	0.38	24.29	0.52
n-Hexyl acetate	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.07	5.88	0.65	0.17	0.02
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	9.04	0.46	27.00	1.38	16.84	0.86	14.53	0.74	49.86	2.55	16.65	1.40	39.97	3.35	41.13	3.45	21.08	1.77	94.21	7.90
Ethyl-3-methylbutanoate	8.17	1.01	22.99	2.85	26.86	3.33	21.09	2.61	69.28	8.58	15.05	1.38	54.47	5.00	50.81	4.67	22.26	2.05	105.44	9.69
Ethyl fatty acids esters																				
Ethyl butanoate	125.11	2.18	293.11	5.12	288.38	5.03	163.57	2.86	341.38	5.96	111.27	18.27	235.21	38.61	294.03	48.27	111.46	18.30	324.92	53.33
Ethyl hexanoate	212.88	13.53	340.82	21.66	303.98	19.32	216.42	13.75	474.06	30.12	178.03	5.01	260.14	7.32	349.75	9.84	219.48	6.17	485.63	13.66
Ethyl octanoate	80.79	4.45	125.86	6.93	51.04	2.81	128.44	7.08	97.29	5.36	35.87	4.88	47.61	6.48	39.67	5.40	24.89	3.39	60.07	8.18
Ethyl decanoate	9.23	1.18	16.58	2.12	9.30	1.19	12.97	1.66	16.43	2.10	2.83	0.42	7.65	1.13	3.51	0.52	3.21	0.47	5.70	0.84
Ethyl-3-hydroxybutanoate	182.39	12.28	196.64	13.24	201.81	13.59	76.73	5.17	169.33	11.40	165.03	7.78	150.22	7.08	238.90	11.27	26.19	1.24	167.75	7.91
Ethyl lactate	1266.83	70.56	3325.02	185.20	2757.88	153.61	515.24	28.70	3827.27	213.18	2055.05	137.08	4117.62	274.65	4032.93	269.00	1050.59	70.08	3969.64	264.78
Fatty acids																				
3-Methylbutanoic acid	305.61	27.59	527.66	47.63	239.03	21.58	252.45	22.79	542.80	49.00	276.04	23.82	228.03	19.67	239.23	20.64	166.50	14.37	253.80	21.90
Hexanoic acid	1175.82	203.42	1107.53	191.61	968.78	167.60	929.77	160.86	2611.48	451.80	1063.90	5.28	987.69	4.91	1168.87	5.81	679.51	3.38	1501.09	7.46
Octanoic acid	2371.29	54.53	2328.44	53.54	2089.89	48.06	2749.01	63.21	2698.64	62.06	2903.52	431.75	2456.54	365.28	3479.60	517.41	2224.57	330.79	2906.85	432.24
Terpenes																				
trans-Linaloloxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cis-Linaloloxide	0	0	0	0	0	0.304056	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linalool	5.105	0.13435	13.165	0.205061	8.325	0.304056	9.18	0.749533	17.5	0.707107	7.204865	0.105875	4.25	0.79196	7.38	0.480833	10.96	1.357645	1.055	0.077782
α-Terpineol	0.97	0	3.31	0.098995	2.03	0.070711	2.25	0.19799	4.775	0.26163	2.94705	0.004172	7.125	0.148492	6.415	0.813173	2.95	0.070711	8.055	0.33234
β-Citronellol	25.095	1.562706	13.64	1.994041	11.155	0.289914	17.555	3.44361	5.52	0.636396	19.02319	0.094491	6.61	0.155563	7.79	1.583919	11.02	0.028284	3.62	0.39598
Geraniol	4.56	0.622254	7.425	0.190919	4.015	0.714178	6.88	1.244508	7.685	0.784889	0	0	0	0	0	0	0.75	0.01	0	0
α-Terpinen	0.13	0	0.2	0.042426	0.23	0.014142	0.21	0	0.24	0	0.174165	0.00589	0.22	0.014142	0.3	0.113137	0.24	0.127279	0.075	0.106066
1,4-Cineole	0	0	0	0	0	0	0	0	0	0	0.23436	0.007976	0.475	0.007071	0.4	0.007071	0.215	0.021213	0.4	0.028284
Limonene	0.42	0	0.72	0.113137	0.695	0.035355	0.615	0.021213	1.09	0.070711	0.46414	0.005855	0.73	0.014142	1.09	0.127279	0.94	0.084853	0.64	0.028284
1,8-Cineole	0	0	0	0	0	0	0	0	0	0	0.049475	0.000742	0.255	0.007071	0.21	0.014142	0.055	0.007071	0.52	0.028284
p-Cymene	0.265	0.007071	0.32	0.028284	0.375	0.021213	0.27	0.042426	0.405	0.021213	0.30945	0.013364	0.42	0.028284	0.4	0.056569	0.34	0	0.36	0.014142
Terpinen-4-ol	5.375	0.318198	3.42	0.212132	3.585	0.049497	6.28	0.339411	0.605	0.06364	5.19176	0.115626	3.05	0.042426	3.795	0.26163	3.3	3.804234	7.85	0.1
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.72	0.30	3.76	0.10	1.20	0.03	0.00	0.00
Noirsoprenoids																				
β-Damascenone	4.515	0.120208	6.515	0.813173	4.275	0.148492	1.995	0.106066	3.695	0.049497	5.48379	0.150204	5.835	0.148492	4.69	0.608112	3.775	0.049497	5.015	0.33234
3-Hydroxy-βdamascone	0.21	0.01	0.90	0.06	0.40	0.03	0.49	0.03	0.41	0.03	0.49	0.07	0.47	0.06	0.39	0.05	0.35	0.05	0.77	0.11
Vitispirane	1.071	0.207889	3.129	0.267286	3.171	0.148492	0.924	0.059397	16.947	0.623668	15.21643	0.255169	33.075	0.207889	32.382	0.534573	4.705	0.417193	112.6941	9.403106
TPB	0.084	0	0.168	0	0.126	0	0.084	0	0.294	0	0.163716	0.006058	0.924	0.059397	0.693	0.089095	0.205	0.007071	1.638	0.059397
TDN	0.851	0.043841	1.134	0	0.882	0.059397	0.336	0.059397	4.893	0.267286	2.722545	0.129337	8.505	0.089095	8.421	0.207889	2.573	0.103238	33.852	0.712764
3-Oxo-α-ionol	2.06	0.28	5.53	0.76	1.93	0.27	1.96	0.27	2.54	0.35	1.08	0.19	1.59	0.27	2.59	0.45	1.24	0.21	0.36	0.06
Benzenoids																				
Furfural	2.98	0.13	11.48	0.52	9.16	0.41	8.20	0.37	5.72	0.26	238.73	37.51	231.08	36.31	150.10	23.59	68.55	10.77	52.34	8.22
Benzaldehyde	28.06	1.44	31.67	1.62	14.75	0.76	21.39	1.10	6.81	0.35	134.22	2.99	41.71	0.93	21.55	0.48	6.18	0.14	3.06	0.07
Benzyl alcohol	234.29	28.62	340.38	41.57	216.82	26.48	232.82	28.44	284.35	34.73	154.17	25.31	221.83	36.41	216.20	35.49	132.23	21.71	151.24	24.83
Vanillin	7.02	0.89	20.26	2.57	9.18	1.16	13.29	1.69	11.39	1.44	7.80	0.23	9.45	0.28	9.29	0.28	11.08	0.33	12.61	0.38
Methyl-vanillate	5.97	1.19	12.60	2.52	7.51	1.50	10.03	2.01	9.01	1.80	3.19	0.36	8.77	0.98	9.75	1.09	8.85	0.99	11.27	1.26
Ethyl-vanillate	129.33	14.48	227.06	25.43	124.43	13.94	155.50	17.41	101.42	11.36	8.61	0.02	88.78	0.25	130.56	0.37	115.94	0.33	89.34	0.25
Methyl salycilate	0	0	0	0	0	0	0	0	0	0	0.128635	0.00193	0.63	0.070711	0.305	0.431335	0	0	0.91	1.286934
2,6-dimethoxy-phenol	10.85	2.02	11.17	2.08	10.86	2.02	15.29	2.85	12.52	2.33	12.21	0.78	23.70	1.52	22.21	1.42	23.75	1.52	19.10	1.22
Eugenol	7.35	0.78	9.32	0.99	5.78	0.61	0.56	0.06	3.75	0.40	3.43	0.59	11.20	1.94	6.09	1.05	6.08	1.05	0.41	0.07
Others																				
γ-Nonalactone	6.82	0.53	7.95	0.62	7.32	0.57	11.75	0.92	7.13	0.56	7.14	1.10	7.45	1.15	12.49	1.93	4.17	0.64	7.41	1.14

V1-5 is short for Vineyards 1-5

Appendix 4.3.10. Concentration (µg/L) and standard deviation (± µg/L) of free compounds of T16 and T40 2018 withered Corvinone wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	d.s.	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	131.85	16.10	78.52	6.24	164.92	20.14	69.97	8.54	165.54	7.69	28.26	2.48	61.36	0.13	160.57	14.11	122.51	2.48	156.34	39.73
Isoamyl alcohol	710093.34	57289.51	207712.24	12558.63	340315.00	27456.22	390164.06	31477.99	240083.28	8442.70	380001.26	8738.26	231124.38	6409.00	355691.95	8179.26	212120.05	8595.92	256052.72	17549.14
1-Pentanol	137.83	5.22	97.55	4.70	174.49	6.60	72.92	2.76	150.94	28.23	18.47	0.55	91.47	0.91	90.86	2.70	9.38	0.04	75.25	13.47
Phenylethyl alcohol	39753.03	4888.63	21428.62	2195.57	36278.59	4461.36	21215.11	2608.93	14266.11	1196.84	42866.29	7569.24	16412.78	234.46	16226.05	2865.16	22648.47	922.67	6507.81	896.59
Methionol	534.56	17.00	406.11	6.89	986.46	31.37	356.50	11.34	391.38	29.31	443.81	6.21	379.88	16.15	503.71	7.05	289.23	4.13	194.83	18.05
C_6 alcohols																				
1-Hexanol	3407.25	251.21	844.15	81.63	2525.85	186.22	2202.33	162.37	2325.86	104.57	1928.08	88.69	888.73	1.26	2017.51	92.80	1983.36	14.09	1846.68	302.93
trans-3-Hexen-1-ol	50.90	7.68	13.78	0.47	58.35	8.81	27.58	4.16	57.70	0.85	35.71	4.96	19.62	0.32	51.05	7.10	24.79	0.02	53.45	0.14
cis-3-Hexen-1-ol	70.41	1.26	38.44	3.95	34.17	0.61	37.69	0.67	43.45	4.10	74.44	5.72	38.33	1.22	30.63	2.35	39.53	1.00	41.39	7.79
cis-2-Hexen-1-ol	20.27	2.29	32.78	2.18	19.10	2.16	10.40	1.18	16.22	0.26	1.67	0.08	20.49	0.03	17.37	0.84	22.61	0.76	14.36	1.17
Esters																				
Isoamyl acetate	222.24	33.80	148.12	3.30	427.58	65.03	357.04	54.30	406.11	6.89	170.65	13.01	111.44	1.75	311.77	23.78	472.19	12.13	301.52	17.89
2-Phenethyl acetate	21.81	2.32	22.27	0.90	26.70	2.84	20.23	2.15	28.61	0.74	14.04	0.30	16.74	0.56	18.47	0.40	24.30	0.12	20.72	3.18
n-Hexyl acetate	0.00	0.00	2.50	0.71	10.25	1.12	8.62	0.95	#DIV/0!	#DIV/0!	0.95	0.10	0.00	0.00	0.48	0.05	4.06	0.01	0.00	0.00
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	22.02	1.13	14.92	1.67	11.03	0.56	9.65	0.49	13.56	0.78	24.02	2.01	21.17	0.93	18.38	1.54	17.34	0.12	22.48	2.04
Ethyl-3-methylbutanoate	23.29	2.88	17.12	1.12	15.07	1.87	11.47	1.42	18.50	0.71	31.12	0.10	28.07	0.43	25.28	2.32	25.18	0.49	29.49	2.07
Ethyl fatty acids esters																				
Ethyl butanoate	202.49	3.54	142.89	8.00	260.46	4.55	158.31	2.76	97.56	8.57	222.29	36.49	131.46	1.29	217.11	35.64	171.70	6.15	83.25	22.24
Ethyl hexanoate	384.64	24.44	193.65	7.38	400.62	25.46	287.20	18.25	313.11	25.32	322.95	9.08	157.35	4.31	238.74	6.71	148.82	1.16	182.06	8.28
Ethyl octanoate	74.25	4.09	69.00	1.59	78.32	4.32	63.45	3.50	58.50	2.12	62.82	8.55	33.95	0.34	35.32	4.81	44.80	1.16	27.41	6.19
Ethyl decanoate	16.57	2.12	11.24	1.72	14.14	1.81	7.92	1.01	10.81	0.42	0.90	0.13	3.44	0.08	5.54	0.82	3.60	0.11	4.41	0.26
Ethyl-3-hydroxybutanoate	141.91	9.56	106.77	3.15	159.54	10.74	66.21	4.46	75.00	5.66	167.46	7.90	98.74	1.41	157.00	7.40	122.35	2.05	76.20	7.28
Ethyl lactate	2088.74	116.34	2009.21	137.15	1275.64	71.05	810.42	45.14	1098.61	138.26	2521.84	168.21	3142.65	95.67	1718.15	114.60	1269.71	19.05	1525.53	175.29
Fatty acids																				
3-Methylbutanoic acid	589.14	53.18	161.89	20.90	457.05	41.26	159.30	14.38	378.61	18.11	330.11	28.48	131.24	2.54	206.34	17.80	180.88	3.28	181.07	9.38
Hexanoic acid	1215.90	210.36	1490.62	142.13	2371.59	410.30	766.12	132.54	1065.85	54.36	129.07	0.64	638.34	16.83	1241.14	6.16	903.07	37.20	567.32	123.78
Octanoic acid	2295.61	52.79	1764.83	177.19	2341.35	53.84	1588.87	36.54	1998.57	42.83	2806.22	417.28	1741.61	7.37	2598.85	386.44	2128.74	75.61	2212.01	332.34
Terpenes																				
trans-Linaloloxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cis-Linaloloxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linalool	11.88	0.876812	7.245	0.346482	6.205	0.091924	8.48	0.226274	14.55	2.008183	11.35	0.622254	1.965	0.148492	6.345	0.756604	8.575	0.318198	2.43	0.226274
α-Terpineol	3.14	0.19799	1.145	0.120208	1.63	0.098995	1.87	0.183848	8.7	0.820244	7.76	0.381838	5.24	0.240416	3.835	0.06364	4.295	0.219203	10.005	0.799031
β-Citronellol	11.44	0.537401	12.68	0.961665	13.325	0.643467	14.625	0.077782	9.195	0.33234	8.25	1.018234	4.02	0.46669	8.465	0.035355	10.385	0.784889	4.795	0.898026
Geraniol	5.085	0.120208	3.18	0.254558	6.225	0.318198	5.12	0	4.67	0.014142	0		0	0	0.56	0.03	0	0	0	0
α-Terpinen	0.19	0.014142	0.145	0.06364	0.23	0.098995	0.105	0.007071	0.235	0.021213	0.33	0.084853	0.155	0.007071	0.17	0.014142	0.15	0.056569	0.145	0.007071
1,4-Cineole	0	0	0	0	0	0	0	0	0	0	0.18	0	0.21	0.014142	0.105	0.007071	0.1	0	0.375	0.01
Limonene	0.835	0.162635	0.525	0.007071	0.485	0.021213	0.545	0.035355	1.435	0.06364	0.99	0	0.62	0.042426	0.62	0.028284	0.64	0.056569	0.9	0.113137
1,8-Cineole	0	0	0	0	0	0	0	0	0	0	0.165	0.007071	0.135	0.007071	0.115	0.021213	0.065	0.007071	0.375	0.035355
p-Cymene	0.265	0.007071	0.14	0	0.23	0	0.18	0	0.305	0.049497	0.345	0.06364	0.26	0.014142	0.25	0.014142	0.17	0	0.225	0.007071
Terpinen-4-ol	0.99	0.084853	1.385	0.077782	2.045	0.06364	1.5	0.042426	0.445	0.035355	0.965	0.148492	1.055	0.091924	1.885	0.049497	1.275	0.26163	8.35	0.1
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.01	0.05	0.88	0.01	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!
Noirsoprenoids																				
β-Damascenone	5.585	0.091924	5.75	0.070711	6.225	0.318198	2.705	0.049497	6.585	0.049497	5.135	0.13435	4.28	0.268701	6.025	0.459619	3.59	0.084853	6.5	0.113137
3-Hydroxy-βdamascone	0.23	0.02	0.18	0.01	0.32	0.02	0.18	0.01	0.36	0.08	0.01	0.00	0.23	0.01	0.39	0.05	0.24	0.01	0.45	0.19
Vitispirane	7.434	0.200818	2.728	0.056569	4.852	0.209304	3.591	0.148492	42.798	0.772161	28.098	3.801406	50.295	3.474723	28.476	0.712764	21.777	0.029698	143.892	12.11698
TPB	0.126	0	0.042	0	0.092	0.011314	0.042	0	0.294	0	0.273	0.029698	0.651	0.029698	0.336	0	0.168	0	1.151	0.213546
TDN	1.906	0.147078	3.234	0	0.87	0.042426	0.462	0.059397	8.211	0.148492	5.964	0.070711	19.11	1.900703	7.518	0.237588	3.318	0	51.765	6.325777
3-Oxo-α-ionol	1.94	0.27	1.30	0.25	3.24	0.45	1.09	0.15	5.02	0.73	0.15	0.03	1.34	0.04	2.34	0.40	1.12	0.05	3.54	0.58
Benzenoids																				
Furfural	7.41	0.33	6.28	1.17	1.18	0.05	2.59	0.12	0.99	0.02	377.05	59.25	112.82	3.92	216.11	33.96	187.77	5.84	191.99	42.75
Benzaldehyde	17.47	0.90	27.66	4.70	0.31	0.02	0.44	0.02	24.50	0.71	0.78	0.02	1.32	0.03	27.38	0.61	0.56	0.01	26.50	0.50
Benzyl alcohol	96.41	11.78	68.42	3.63	130.55	15.94	35.90	4.39	161.80	1.77	2.71	0.44	56.48	1.83	58.54	9.61	33.90	0.53	68.23	2.15
Vanillin	11.14	1.41	8.89	0.16	9.32	1.18	6.10	0.77	10.40	0.36	2.19	0.07	7.45	0.20	11.46	0.34	9.27	0.08	12.59	0.79
Methyl-vanillate	20.01	4.01	9.18	0.38	10.92	2.19	7.67	1.54	21.67	3.89	19.42	2.16	10.21	0.18	15.51	1.73	9.22	0.19	32.59	15.46
Ethyl-vanillate	160.51	17.98	91.26	1.61	337.98	37.85	114.92	12.87	305.98	10.15	83.10	0.23	82.19	3.23	215.31	0.61	118.27	4.63	204.96	15.61
Methyl salycilate	0	0	0	0	0	0	0	0	0	0	0	0	0.315	0.445477	0.22	0.311127	0.195	0.275772	0.5	0.707107
2,6-dimethoxy-phenol	10.56	1.97	5.37	0.55	10.35	1.93	8.10	1.51	10.98	0.23	3.83	0.25	11.41	0.42	21.90	1.40	11.25	0.19	23.53	5.39
Eugenol	2.80	0.30	1.06	0.05	3.95	0.42	0.82	0.09	4.07	0.08	0.26	0.04	2.07	0.06	0.29	0.05	1.40	0.04	0.31	0.09
Others																				
γ-Nonalactone	7.56	0.59	8.00	0.18	9.01	0.70	4.28	0.33	12.77	1.47	7.45	1.15	6.27	0.10	13.25	2.04	6.49	0.14	19.09	0.74

V1-5 is short for Vineyards 1-5

Appendix 4.3.11. Concentration (μg/L) and standard deviation (± μg/L) of free compounds of T16 and T40 2019 withered Corvina wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	d,s,	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	137.55	12.01	260.22	13.84	246.65	43.46	180.88	21.35	299.38	41.81	119.43	21.70	227.23	10.22	189.39	0.21	5.71	135.18	201.72	3.67
Isoamyl alcohol	129101.07	5127.00	260229.70	24642.30	125989.68	16653.35	123044.16	14373.69	106746.73	6224.77	118492.53	18149.71	191523.99	12131.15	107907.32	2857.58	4919.72	101938.44	90725.87	260.38
1-Pentanol	313.67	43.47	356.51	114.37	433.65	29.68	360.89	61.77	483.67	63.75	363.16	13.13	425.89	2.02	447.69	67.19	6.79	395.51	465.74	14.72
Phenylethyl alcohol	11619.83	139.92	17090.40	3776.50	12294.35	1737.49	12586.22	2163.59	8245.58	31.73	10766.87	2315.41	18738.31	910.57	11641.96	173.64	229.82	9994.17	7339.66	722.02
Methionol	75.89	4.86	294.32	8.04	96.21	18.82	77.72	4.84	60.33	7.28	105.50	15.47	333.62	35.90	105.74	3.89	3.17	86.74	90.40	5.44
C_6 alcohols																				
1-Hexanol	1777.49	92.26	2026.66	152.55	1851.80	268.52	1440.92	111.62	1994.11	85.49	1653.19	173.61	2087.73	182.67	1628.92	8.97	23.63	1301.98	1766.21	17.39
trans-3-Hexen-1-ol	12.72	0.71	15.30	1.69	13.12	2.32	10.14	0.01	14.92	0.92	13.01	0.51	14.74	3.63	11.58	0.04	0.35	9.84	13.11	0.35
cis-3-Hexen-1-ol	196.58	14.12	230.21	26.86	119.57	20.36	100.86	5.98	128.67	5.83	183.30	18.31	240.71	43.25	100.67	0.50	3.34	93.12	110.97	0.59
cis-2-Hexen-1-ol	13.55	0.11	12.36	0.88	13.42	0.54	11.27	0.38	14.32	0.61	13.75	0.39	16.14	2.18	13.06	0.28	0.47	13.12	14.43	0.94
Esters																				
Isoamyl acetate	172.29	2.36	356.83	5.07	249.90	33.01	152.53	16.13	243.40	7.32	189.86	3.76	271.78	16.65	251.73	70.27	5.84	179.30	278.67	11.87
2-Phenethyl acetate	21.42	0.57	25.84	0.32	22.52	2.42	20.06	1.41	20.54	0.23	21.85	0.90	27.68	4.32	23.95	4.62	0.53	22.95	22.27	0.20
n-Hexyl acetate	0.19	0.02	1.64	2.19	0.05	0.06	0.20	0.22	0.21	0.17	1.03	1.24	0.29	0.21	2.54	3.59	0.00	0.10	0.05	3.24
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	10.20	0.13	12.93	0.09	17.54	1.38	6.33	0.96	11.24	0.25	15.91	0.20	31.02	1.73	37.51	2.30	0.33	11.52	20.08	3.01
Ethyl-3-methylbutanoate	8.72	1.51	19.65	1.02	22.31	2.05	5.71	0.08	15.05	0.49	23.43	1.45	46.52	1.46	52.27	12.00	0.05	9.32	33.72	3.06
Ethyl fatty acids esters																				
Ethyl butanoate	126.74	6.28	213.04	13.33	176.53	14.36	109.08	3.12	121.64	4.14	131.74	11.22	252.48	26.69	198.89	9.02	4.31	118.02	136.38	3.86
Ethyl hexanoate	154.18	9.44	306.10	3.77	209.01	11.48	153.51	32.64	134.77	1.80	130.98	14.62	302.65	1.28	213.025	17.35	3.19	164.74	120.67	21.47
Ethyl octanoate	27.85	3.28	78.32	0.69	47.69	4.00	35.71	0.60	27.50	2.86	16.66	1.11	60.71	5.93	36.28	0.51	0.50	29.30	15.01	2.47
Ethyl decanoate	5.85	0.93	15.02	1.80	11.55	1.45	8.48	0.87	8.48	0.34	4.35	0.69	10.47	0.61	7.00	0.44	0.06	6.20	5.55	0.63
Ethyl-3-hydroxybutanoate	39.04	6.99	256.38	160.68	94.27	10.13	36.04	7.17	77.41	6.55	40.06	7.58	146.09	7.75	85.84	8.61	0.28	26.77	66.38	3.49
Ethyl lactate	430.62	44.19	3419.08	725.12	2529.98	381.63	326.93	52.32	1642.49	199.71	646.82	133.35	5569.77	363.57	2969.36	266.28	10.94	462.65	2109.39	121.71
Fatty acids																				
3-Methylbutanoic acid	549.26	22.55	449.01	81.19	330.87	32.76	263.43	9.21	371.54	28.13	492.42	64.31	461.01	125.55	263.39	19.30	5.22	234.31	295.36	3.30
Hexanoic acid	1071.75	3.91	1554.91	80.25	1284.80	123.40	1058.10	26.95	912.90	32.68	1061.46	12.50	1610.78	2.84	1140.34	65.97	44.57	985.08	790.15	6.17
Octanoic acid	1762.50	59.21	2470.47	103.24	2176.85	72.95	2052.28	35.28	1361.94	51.51	1795.70	3.86	2481.69	7.54	2046.54	169.01	102.05	2050.20	1315.52	67.40
Terpenes																				
trans-Linaloloxide																				
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	6.34	2.09	18.63	2.04	12.11	0.47	7.86	0.14	18.58	0.29	9.80	1.19	9.66	0.54	3.36	0.35	0.37	9.80	15.44	1.43
α-Terpineol	1.82	0.18	9.54	0.53	7.06	0.61	1.97	0.28	9.52	0.15	5.18	0.14	16.29	0.47	10.34	0.66	0.16	3.64	17.22	0.56
β-Citronellol	10.89	0.52	8.12	0.18	5.25	0.38	9.07	0.40	6.67	0.19	9.79	1.00	5.49	0.13	3.66	0.18	0.52	7.81	4.35	0.39
Geraniol	7.13	0.12	4.19	0.28	4.97	0.49	2.64	0.14	4.40	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
α-Terpinen	1.16	0.01	0.46	0.01	0.52	0.01	0.28	0.01	0.76	0.00	0.20	0.01	0.29	0.04	0.26	0.02	0.01	0.24	0.30	0.02
1,4-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.39	0.00	0.02	0.09	0.17	0.00
Limonene	0.50	0.02	1.96	0.07	1.13	0.04	0.82	0.32	2.45	0.03	0.55	0.03	1.42	0.08	0.85	0.04	0.05	0.60	1.80	0.17
1,8-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.01	0.19	0.03	0.00	0.00	0.26	0.00
p-Cymene	3.11	0.10	0.78	0.00	0.66	0.04	0.45	0.03	0.84	0.04	2.77	0.32	0.65	0.10	0.62	0.02	0.00	0.44	0.59	0.00
Terpinen-4-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.66	0.48	4.07	0.55	0.00	0.00	4.34	0.07
Noirsoprenoids																				
β-Damascenone	2.47	0.23	4.46	0.07	2.36	0.08	3.31	0.21	3.09	0.10	4.29	0.50	4.00	0.01	2.76	0.02	0.21	4.50	3.19	0.06
3-Hydroxy-βdamascone	0.23	0.02	0.21	0.01	0.16	0.05	0.26	0.00	0.26	0.00	0.25	0.04	0.16	0.00	0.20	0.00	0.01	0.25	0.18	0.00
Vitispirane	2.92	0.15	9.41	0.72	21.95	1.10	2.73	0.24	17.58	0.51	15.48	1.22	32.63	4.04	47.73	1.10	0.21	6.49	38.81	4.48
TPB	0.04	0.00	0.13	0.00	0.17	0.02	0.04	0.00	0.13	0.00	0.06	0.01	0.40	0.03	0.57	0.03	0.03	0.15	0.44	0.00
TDN	0.69	0.13	3.13	0.15	6.70	0.03	0.80	0.04	4.06	0.20	3.15	0.12	13.90	1.62	21.00	0.18	0.06	2.02	15.35	0.77
3-Oxo-α-ionol	5.175	0.035355	3.015	0.007071	3.35	0.212132	6.515	0.671751	7.365	0.106066	5.155	0.247487	2.97	0.141421	3.095	0.304056	0.266523	6.79154	6.632415	0.021213
Benzenoids																				
Furfural	13.67	0.7	12.57	0.03	11.07	1.29	9.16	2.31	21.51	0.49	340.80	54.24	175.34	2.63	157.72	0.85	2.47	207.46	486.96	1.29
Benzaldehyde	120.75	15.71	9.90	0.74	14.38	1.63	204.15	12.71	102.85	3.90	97.71	5.28	8.30	0.84	10.93	0.22	2.03	170.21	93.72	0.64
Benzyl alcohol	190.15	6.79	322.04	77.15	170.42	17.74	101.15	68.51	157.92	10.99	185.97	25.41	346.56	104.15	142.93	6.38	3.24	132.28	140.34	3.21
Vanillin	41.26	3.30	14.55	2.11	19.71	0.81	14.80	0.25	26.49	0.11	45.97	2.35	17.10	1.39	18.06	0.54	0.47	14.03	28.55	1.86
Methyl-vanillate	13.06	0.91	14.83	2.12	11.80	0.82	8.62	2.14	21.38	0.62	14.81	0.47	10.43	1.11	11.38	0.02	0.33	8.98	18.53	0.71
Ethyl-vanillate	828.14	0.69	154.99	10.43	172.31	2.72	221.11	19.31	348.22	8.86	781.87	27.00	158.61	25.05	177.17	40.67	5.96	226.02	348.68	4.84
Methyl salycilate	0.10	0.01	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2,6-dimethoxy-phenol	10.05	1.57	7.87	0.52	10.50	2.11	8.34	0.82	13.39	0.18	16.00	1.61	9.93	3.05	10.28	0.04	0.38	9.67	16.84	0.20
Eugenol	6.88	0.56	12.86	0.78	3.95	0.21	10.64	0.12	5.83	1.17	6.46	1.09	11.12	1.58	2.46	3.08	0.19	10.38	5.10	0.410122
Others																				
γ-Nonalactone	10.32	0.33	10.53	0.43	18.91	4.10	25.69	4.42	7.31	0.57	10.18	0.30	10.28	1.90	18.37	0.56	0.07	26.27	6.85	0.34

V1-5 is short for Vineyards 1-5

Appendix 4.3.12. Concentration (μg/L) and standard deviation (± μg/L) of free a compounds of T16 and T40 2019 withered Corvinone wines

	T16										T40									
	V1		V2		V3		V4		V5		V1		V2		V3		V4		V5	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Alcohols																				
1-Butanol	132.19	7.12	190.33	13.68	179.29	25.17	183.60	10.32	226.20	20.03	124.29	10.05	380.76	121.75	186.71	20.41	140.49	15.27	186.65	3.67
Isoamyl alcohol	122804	1021.87	195802.1	6064.7	206767.0	23420.9	183361.9	9098.6	126102.1	6752.6	125343.2	4626.3	252003.6	68290.5	205870.7	21853.9	174831.7	79.3	119679.0	260.38
1-Pentanol	394.96	13.81	514.5	66.4	533.7	22.3	492.5	21.1	412.5	20.8	378.3	19.0	465.2	2.5	576.8	14.1	478.0	0.4	516.2	14.72
Phenylethyl alcohol	11593.3	404.29	15311.4	1924.9	17692.3	2943.3	15974.4	818.4	11178.0	678.1	13511.5	273.1	16748.1	575.6	16336.1	2234.7	16425.0	687.2	9522.6	722.02
Methionol	87.90	6.76	556.00	65.06	464.90	90.69	360.32	32.62	118.53	8.69	112.96	7.66	616.03	19.76	536.96	11.98	312.99	52.05	130.57	5.44
C_6 alcohols																				
1-Hexanol	1991.48	14.65	2954.64	286.39	2769.67	387.90	2000.76	108.07	2503.80	104.06	2060.20	73.08	3028.97	208.71	2717.97	298.17	1932.24	21.51	2503.42	17.39
trans-3-Hexen-1-ol	15.87	0.88	33.37	5.43	25.45	2.91	21.35	1.42	21.61	0.96	15.94	0.67	33.83	5.91	26.12	1.68	19.45	0.70	22.85	0.35
cis-3-Hexen-1-ol	31.90	1.24	56.66	10.09	38.65	6.53	36.10	3.65	28.38	0.66	30.32	2.37	57.56	9.55	38.96	4.40	33.82	1.57	33.52	0.59
cis-2-Hexen-1-ol	14.14	0.82	16.01	1.37	D	0.01	14.33	1.32	12.56	0.80	14.09	1.54	12.51	3.65	14.57	1.27	13.50	1.10	14.75	0.94
Esters																				
Isoamyl acetate	271.23	10.68	275.26	32.08	177.24	13.79	432.69	41.68	232.21	13.79	319.54	10.76	255.77	1.72	160.63	28.49	372.36	59.16	282.17	11.87
2-Phenethyl acetate	28.72	1.36	25.29	2.12	19.84	1.49	31.73	3.57	18.93	0.47	31.71	1.56	25.87	5.06	19.51	1.50	29.82	4.29	21.74	0.20
n-Hexyl acetate	0.10	0.00	4.01	0.64	0.13	0.06	3.45	0.06	0.11	0.01	1.83	2.46	3.77	0.35	0.06	0.08	1.47	1.87	2.48	3.24
Branched-chain fatty acids ethyl esters																				
Ethyl-2-methylbutanoate	12.80	0.15	12.66	0.49	10.15	0.37	7.90	0.81	8.91	0.76	30.68	1.88	28.24	0.76	19.08	1.51	16.88	2.18	19.98	3.01
Ethyl-3-methylbutanoate	14.82	1.32	14.80	0.21	13.52	2.57	7.97	0.05	14.85	2.76	37.54	4.26	35.21	0.11	27.37	1.46	20.74	1.53	33.79	3.06
Ethyl fatty acids esters																				
Ethyl butanoate	122.13	3.01	195.90	19.38	216.10	16.98	167.66	3.20	146.77	3.32	166.19	4.16	229.88	29.41	221.64	2.45	179.95	5.85	176.56	3.86
Ethyl hexanoate	192.86	30.21	336.41	4.29	302.65	4.86	248.30	34.72	176.07	1.23	208.80	20.29	309.76	7.45	248.20	24.90	233.25	48.34	178.29	21.47
Ethyl octanoate	40.42	1.77	94.00	11.23	83.52	3.12	66.70	8.55	25.09	3.34	24.61	0.37	53.46	5.89	38.07	6.57	31.58	2.04	23.14	2.47
Ethyl decanoate	10.17	1.98	21.41	2.48	19.78	2.38	14.06	0.99	10.23	0.78	4.44	0.76	10.39	0.93	6.32	0.62	4.50	0.32	4.41	0.63
Ethyl-3-hydroxybutanoate	62.26	4.00	166.33	6.61	162.07	31.32	82.36	11.31	41.72	2.45	67.34	7.09	289.72	36.47	158.72	29.85	77.01	7.38	48.89	3.49
Ethyl lactate	703.32	74.57	1319.16	164.98	1012.93	218.07	437.78	65.53	1219.45	133.91	1114.96	131.61	4428.05	45.76	1987.60	64.13	707.88	150.39	1943.07	121.71
Fatty acids																				
3-Methylbutanoic acid	315.37	4.16	526.02	96.60	492.26	35.97	420.25	12.96	372.00	15.43	303.25	7.43	527.27	100.88	463.29	52.09	391.05	1.73	360.96	3.30
Hexanoic acid	1492.92	3.49	1875.58	20.56	1813.05	152.69	1613.00	46.87	1124.31	4.32	1504.47	9.59	1903.89	31.23	1679.73	196.64	1590.55	7.82	1164.82	6.17
Octanoic acid	2816.99	61.39	2776.77	12.52	2747.04	23.57	2850.55	96.34	1778.39	32.53	2798.33	70.51	2786.19	15.20	2724.19	34.41	2910.28	157.52	1868.06	67.40
Terpenes																				
trans-Linaloloxide																				
cis-Linaloloxide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Linalool	10.17	0.49	13.76	1.31	14.65	0.27	12.15	0.25	14.75	0.06	5.50	0.55	7.09	0.06	10.79	0.28	11.89	0.01	10.46	1.43
α-Terpineol	7.68	0.05	8.51	1.45	6.73	0.66	5.11	0.26	7.54	0.45	9.30	1.32	9.58	0.47	9.91	0.16	8.02	1.46	10.71	0.56
β-Citronellol	5.97	0.16	7.86	1.08	6.91	0.36	7.15	0.21	5.47	0.27	4.33	0.37	4.26	0.20	5.09	0.50	5.67	0.49	4.99	0.39
Geraniol	4.33	0.11	6.71	0.64	4.45	0.08	3.42	1.03	5.10	0.54	2.86	0.04	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
α-Terpinen	0.27	0.00	0.15	0.00	0.31	0.05	0.43	0.01	0.24	0.05	0.19	0.01	0.12	0.01	0.20	0.00	0.31	0.04	0.18	0.02
1,4-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.04	0.00	0.00	0.16	0.02	0.24	0.01	0.00	0.00
Limonene	0.73	0.04	0.85	0.08	1.13	0.05	1.02	0.04	1.78	0.12	0.59	0.08	0.67	0.00	0.80	0.01	0.79	0.05	1.21	0.17
1,8-Cineole	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.11	0.01	0.10	0.00	0.20	0.00
p-Cymene	0.47	0.02	0.28	0.03	0.43	0.03	0.53	0.04	0.47	0.01	0.36	0.01	0.24	0.01	0.28	0.00	0.41	0.01	0.33	0.00
Terpinen-4-ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p-Menthane-1,8-diol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.02	2.13	0.18	1.04	0.05	2.00	0.00	3.25	0.07
Noirsoprenoids																				
β-Damascenone	2.74	0.04	6.22	0.37	7.40	0.31	5.05	0.13	3.90	0.02	2.36	0.47	4.59	0.11	6.46	0.05	4.06	0.66	3.94	0.06
3-Hydroxy-βdamascone	0.11	0.00	0.13	0.03	0.20	0.03	0.21	0.01	0.13	0.02	0.11	0.01	0.08	0.00	0.13	0.02	0.13	0.01	0.16	0.00
Vitispirane	30.29	0.94	19.15	0.97	20.62	3.33	13.29	0.98	37.97	1.84	48.03	3.59	40.70	0.71	32.93	1.60	20.64	0.50	61.01	4.48
TPB	0.12	0.01	0.11	0.02	0.08	0.00	0.06	0.03	0.10	0.00	0.25	0.03	0.23	0.03	0.21	0.00	0.15	0.03	0.25	0.00
TDN	4.21	0.07	4.07	0.65	3.36	0.53	1.74	0.03	5.36	0.21	9.41	1.13	10.61	0.15	8.76	0.56	4.26	0.27	13.73	0.77
3-Oxo-α-ionol	2.785	0.091924	3.22	0.212132	4.85	0.226274	5.7	0.070711	5.075	0.06364	2.785	0.304056	2.815	0.007071	4.93	0.056569	5.345	0.360624	5.825	0.021213
Benzenoids																				
Furfural	6.91	0.13	6.60	0.57	10.54	0.34	6.71	0.66	12.51	0.74	164.19	26.66	359.98	50.48	375.80	40.07	220.81	33.97	270.23	1.29
Benzaldehyde	12.53	0.09	3.35	0.23	28.82	2.98	13.32	1.27	14.95	1.05	10.69	0.88	3.09	0.10	26.51	2.50	10.88	0.52	13.74	0.64
Benzyl alcohol	40.42	8.00	38.12	2.67	64.65	6.16	59.63	0.52	54.85	0.20	65.73	10.71	61.12	10.20	72.30	8.85	87.92	19.88	63.27	3.21
Vanillin	6.18	1.30	10.34	1.75	9.99	0.62	7.87	0.43	17.60	0.38	13.33	0.81	10.15	0.43	12.20	0.83	8.02	0.04	21.23	1.86
Methyl-vanillate	22.19	2.67	22.73	2.65	25.81	3.52	15.86	2.06	28.52	1.20	20.70	2.43	24.39	3.29	29.48	4.10	15.82	2.29	30.45	0.71
Ethyl-vanillate	377.09	0.59	225.23	11.78	434.45	27.00	137.07	1.89	313.08	25.05	427.58	8.87	216.81	13.36	421.41	20.22	129.54	4.73	354.43	4.84
Methyl salycilate	0.24	0.00	0.30	0.01	0.00	0.00	0.09	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2,6-dimethoxy-phenol	11.77	1.55	8.32	1.01	10.72	2.23	9.93	0.21	13.25	0.39	13.05	1.41	17.81	2.81	19.82	3.44	12.58	1.93	20.49	0.20
Eugenol	2.08	0.11	1.24	0.01	1.82	0.43	3.44	0.48	1.65	0.33	2.01	0.29	1.99	0.48	3.31	0.52	3.32	0.81	2.29	0.410122
Others																				
γ-Nonalactone	23.60	0.73	8.32	0.18	31.77	1.80	16.91	5.28	7.23	1.36	23.42	0.04	6.79	0.69	30.53	1.94	16.26	4.12	7.41	0.34

V1-5 is short for Vineyards 1-5

Appendix 4.3.13. Mann Whitney p-value of T16 vs T40 model aged fresh grapes wines

	2017 Corvina	**2018 Corvina**	**2019 Corvina**	**2017 Corvinone**	**2018 Corvinone**	**2019 Corvinone**
Alcohols						
1-Butanol	0.631	0.684	**0.029**	0.529	0.796	**0.029**
Isoamyl alcohol	0.631	0.247	0.436	0.579	0.739	0.529
1-Pentanol	0.912	**<0.0001**	0.436	0.684	0.481	**0.004**
Phenylethyl alcohol	0.436	**0.009**	0.971	0.912	0.853	0.853
Methionol	0.579	**0.043**	0.631	0.075	0.105	0.393
C_6 alcohols						
1-Hexanol	0.481	0.796	0.912	0.971	0.393	0.853
trans-3-Hexen-1-ol	0.928	0.869	0.631	0.739	0.315	0.971
cis-3-Hexen-1-ol	0.436	0.684	0.853	0.796	0.542	0.631
cis-2-Hexen-1-ol	0.912	0.739	0.218	**0.025**	0.343	**0.025**
Esters						
Isoamyl acetate	**0.029**	**0.000**	0.063	**0.011**	**0.007**	**<0.0001**
2-Phenylethyl acetate	**0.007**	0.096	0.171	**0.000**	0.436	0.190
n-Hexyl acetate	**0.035**	0.446	0.469	0.631	**0.004**	0.095
Branched-chain fatty acids ethyl esters						
Ethyl-2-methylbutanoate	**0.000**	**<0.0001**	**0.003**	**<0.0001**	**0.004**	**0.029**
Ethyl 3-methylbutanoate	**0.001**	0.063	**0.029**	**<0.0001**	**0.001**	**0.003**
Fatty acids ethyl esters						
Ethyl lactate	**0.001**	0.436	0.063	**0.000**	**<0.0001**	**0.023**
Ethyl butanoate	0.247	0.105	0.315	0.089	0.218	0.436
Ethyl-3-hydroxybutanoate	**<0.0001**	0.529	0.739	0.075	0.218	0.393
Ethyl hexanoate	0.971	0.190	0.796	0.481	0.631	0.063
Ethyl octanoate	**0.002**	**0.001**	**0.043**	**0.001**	**<0.0001**	**0.004**
Ethyl decanoate	**<0.0001**	**<0.0001**	**0.014**	**<0.0001**	**0.000**	**0.009**
Fatty acids						
3-Methylbutanoic acid	0.218	0.393	0.684	0.075	0.436	0.853
Hexanoic acid	0.247	0.631	0.315	0.912	0.353	0.631
Octanoic acid	0.631	0.971	**0.023**	0.529	0.393	0.393
Terpenes						
trans-Linaloloxide	**<0.0001**	**<0.0001**	**<0.0001**			**0.001**
cis-Linaloloxide	**0.000**		**<0.0001**	**0.000**	0.474	0.474
Linalol	**<0.0001**	**0.000**	**0.002**	**<0.0001**	**<0.0001**	**<0.0001**
α-Terpineol	0.218	0.305	0.436	0.118	**0.009**	**0.043**
β-Citronellol	**<0.0001**	**0.002**	**<0.0001**	**<0.0001**	**0.000**	**<0.0001**
Geraniol	**0.000**	**<0.0001**	**<0.0001**	**0.000**	**<0.0001**	**<0.0001**
1,4-Cineol	**0.000**	**0.001**	**<0.0001**	**<0.0001**	**0.001**	0.474
Limonene	**<0.0001**	**0.034**	0.343	**0.045**	0.340	0.138
1,8-Cineol	**0.000**	**0.005**	**0.001**	**<0.0001**	**0.001**	**<0.0001**
p-Cymene	**0.000**	0.807	0.492	0.181	0.123	0.641
Terpinen-4-ol	0.868	0.078	0.670	0.566	**0.037**	**0.004**
p-Menthane-1,8-diol	**0.000**	**0.001**	**<0.0001**	**<0.0001**	0.087	**<0.0001**
Nerol	**<0.0001**	**<0.0001**	**<0.0001**		**0.011**	**0.011**
p-Cymenene						
Noirsoprenoids						
β-Damascenone	0.481	0.218	**0.014**	0.086	0.853	0.796
3-Hydroxy-β-damascone	**<0.0001**	0.203		**<0.0001**	**0.000**	
vitispirane 1	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.003**	**<0.0001**
TPB	**<0.0001**	**0.002**	**0.019**	**<0.0001**	**<0.0001**	**<0.0001**
TDN	**<0.0001**	**<0.0001**	**0.000**	**<0.0001**	**0.001**	**<0.0001**
3-Oxo-α-ionol	0.481	0.971	**0.000**	0.448	0.343	0.764
Benzenoids and others						
Furfural	**<0.0001**	**<0.0001**	**0.000**	**<0.0001**	**<0.0001**	**<0.0001**
Benzaldehyde	0.493	**0.043**	**0.007**	0.218	0.954	0.052
Benzyl alcohol	0.315	0.353	0.912	0.631	0.796	0.052
Vanillin	**0.002**	0.165	0.481	0.402	0.247	**0.002**
Methyl-vanillate	0.481	0.927	**0.003**	0.644	0.739	0.971
Ethyl-vanillate	0.912	0.353	**<0.0001**	0.853	0.393	0.739
Methyl salycilate	0.325	0.171	0.150	0.469	0.305	0.367
2,6-Dimethoxy-Phenol	**<0.0001**	**<0.0001**	**0.007**	**0.023**	**0.000**	**<0.0001**
Eugenol	0.050	0.279	0.246	0.342	0.198	0.288
γ-Nonalactone	0.481	0.363	0.725	0.796	0.107	0.897

Bold values shows significant correlation (α=0.05)

Appendix 4.3.14. Mann Withney p-value of T16 vs T40 model aged withered grapes wines, in bold significative results

	Corvina			Corvinone		
Alcohols	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**
1-Butanol	0.853	**0.002**	0.089	0.796	0.436	0.739
Isoamyl alcohol	**0.023**	0.190	0.063	0.123	0.481	0.853
1-Pentanol	0.912	0.123	0.529	0.393	**0.002**	0.739
Phenylethyl alcohol	0.393	0.280	0.481	0.684	0.280	0.796
Methionol	0.971	0.218	**0.043**	0.190	0.123	0.529
C_6 alcohols						
1-Hexanol	0.739	**0.011**	0.280	0.436	**0.015**	0.971
trans-3-Hexen-1-ol	0.631	0.494	0.315	0.631	0.529	0.971
cis-3-Hexen-1-ol	0.739	0.393	0.436	0.481	0.971	0.796
cis-2-Hexen-1-ol	0.165	0.739	0.197	0.971	0.529	0.481
Acetate esters						
Isoamyl acetate	0.089	**0.029**	0.579	**0.015**	0.481	0.631
2-Phenylethyl acetate	0.393	0.165	0.123	0.280	**0.015**	0.698
n-Hexyl acetate	0.468	0.122	0.871	0.955	**0.031**	0.598
Branched-chain fatty acids ethyl esters						
Ethyl-2-methylbutanoate	**0.023**	0.075	**0.004**	**<0.0001**	**0.005**	**<0.0001**
Ethyl 3-methylbutanoate	**0.001**	0.315	**0.007**	**<0.0001**	**0.035**	**<0.0001**
Fatty acids ethyl esters						
Ethyl lactate	0.315	0.165	0.353	0.315	0.075	**0.029**
Ethyl butanoate	0.172	0.353	0.315	0.075	0.739	0.143
Ethyl-3-hydroxybutanoate	0.529	0.280	0.631	0.393	0.353	0.739
Ethyl hexanoate	0.912	0.796	0.912	0.436	**0.005**	0.631
Ethyl octanoate	**0.000**	**0.000**	0.190	**<0.0001**	**0.000**	**0.029**
Ethyl decanoate	**<0.0001**	**<0.0001**	**0.029**	**<0.0001**	**<0.0001**	**0.000**
Fatty acids						
3-Methylbutanoic acid	**0.002**	**0.019**	0.315	0.247	0.165	0.579
Hexanoic acid	0.684	0.684	0.579	0.796	**0.005**	0.971
Octanoic acid	0.579	0.190	0.739	**0.009**	0.123	0.912
Terpenes						
trans-Linaloloxide	**<0.0001**	**<0.0001**	**<0.0001**	**0.000**	**<0.0001**	**<0.0001**
cis-Linaloloxide	**0.005**	**<0.0001**	**<0.0001**	**0.000**	**<0.0001**	**<0.0001**
Linalol	**<0.0001**	**0.023**	0.315	**<0.0001**	0.123	**0.009**
α-Terpineol	0.052	**0.009**	0.063	0.101	**0.009**	**0.001**
β-Citronellol	**<0.0001**	0.105	0.353	**<0.0001**	**0.000**	**0.007**
Geraniol	**0.000**	**0.000**	**<0.0001**	**0.000**	**0.000**	**<0.0001**
1,4-Cineol	**0.001**	**<0.0001**	**0.001**	**0.001**	**<0.0001**	**<0.0001**
Limonene	0.118	0.492	0.436	0.545	0.210	**0.050**
1,8-Cineol	**0.000**	**<0.0001**	**0.011**	**0.000**	**<0.0001**	**<0.0001**
p-Cymene	0.194	**<0.0001**	**<0.0001**	**0.011**	**<0.0001**	**<0.0001**
Terpinen-4-ol	**<0.0001**	0.529	**<0.0001**	**<0.0001**	0.543	**<0.0001**
p-Menthane-1,8-diol	**<0.0001**	**0.001**	**0.025**	**<0.0001**	**0.001**	**<0.0001**
Nerol	0.341	**0.012**	**0.011**	**0.006**	0.511	**<0.0001**
p-Cymenene	0.575	0.170	0.202	0.460	0.544	**0.006**
Norisoprenoids						
β-Damascenone	0.165	0.148	0.101	0.247	0.447	0.315
3-Hydroxy-β-damascone	0.822	0.811	0.321	0.118	0.565	0.088
vitispirane 1	0.240	**0.001**	**0.023**	0.052	**0.003**	**0.005**
TPB	**0.000**	**0.002**	**0.012**	**0.000**	**0.000**	**0.002**
TDN	**<0.0001**	**0.001**	**0.030**	**<0.0001**	**0.003**	**0.001**
3-Oxo-α-ionol	0.543	**0.009**	0.631	0.869	0.280	0.971
Benzenoids						
Furfural	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.000**
Benzaldehyde	0.739	0.853	0.353	**0.007**	0.436	0.280
Benzyl alcohol	0.075	**0.001**	0.393	0.971	**0.009**	**0.005**
Vanillin	0.218	0.393	0.796	**0.029**	0.971	0.123
Methyl-vanillate	0.529	0.971	0.529	**0.019**	0.436	0.684
Ethyl-vanillate	0.912	**0.005**	0.971	0.436	0.143	0.912
Methyl salycilate	**0.030**	**<0.0001**	0.087	0.823	0.087	**<0.0001**
2,6-Dimethoxy-Phenol	**0.029**	**0.001**	0.075	0.075	0.143	**0.001**
Eugenol	**0.000**	0.796	0.529	**<0.0001**	**0.009**	0.218
Others						
γ-Nonalactone	0.684	0.579	0.853	0.631	0.739	0.724

Be careful to trust a person who does not like wine

Karl Marx

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